5-2014

Habitat Assessment of Two Narrowly Endemic Plant Species, Ozark Spiderwort (Tradescantia ozarkana) E. S. Anderson and Woods. And Newton's Larkspur (Delphinium newtonianum) D. M. Moore

Autumn Lynn Coffey Olsen
University of Arkansas, Fayetteville

Habitat Assessment of Two Narrowly Endemic Plant Species, Ozark Spiderwort (*Tradescantia ozarkana*) E. S. Anderson and Woods. And Newton's Larkspur (*Delphinium newtonianum*) D. M. Moore

Habitat Assessment of Two Narrowly Endemic Plant Species, Ozark Spiderwort (*Tradescantia ozarkana*) E. S. Anderson and Woods. And Newton's Larkspur (*Delphinium newtonianum*) D. M. Moore

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Biology

by

Autumn Lynn Coffey Olsen
University of Arkansas
Bachelor of Science in Biology, 2010

May 2014
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Dr. Steven L. Stephenson
Thesis Director

Dr. Johnnie L. Gentry
Committee Member

Dr. Gary Huxel
Committee Member

Dr. Kimberly G. Smith
Committee Member

ABSTRACT

The threat of biodiversity loss is upon us with the onset of climate change and our ever-demanding needs of the Earth's resources for a rapidly growing human population. Species highly vulnerable to loss are those limited in abundance and distribution, or those with reduced genetic diversity. Efforts to actively conserve a sensitive species require effectual data on the probable causes of their vulnerability. Two species of concern, *Delphinium newtonianum* and *Tradescantia ozarkana*, are globally rare endemic vascular plant species found only in the Interior Highlands of North America. In an attempt to understand the causes for their endemism, habitat characterization of eight sites for each species was carried out by means of plant community assessments, soil characterizations, natural history investigations, and Geographic Information Systems (GIS) modeling. Ordination methods were utilized both to examine patterns among the sites and to assess stem density as a function of soil chemistry and physical site characters. Stem density for *T. ozarkana* was found to be significantly correlated with magnesium, copper, zinc, and phosphorus soil content. In contrast, ordination methods identified few factors that were clearly important for *D. newtonianum* habitat. GIS was used both as tool for habitat data collection on scales not possible by field measurements and for basic habitat modeling to test the predictability of delineating habitat area using easily accessable GIS layers without prior knowledge of habitat parameter importance levels. Although projected habitat modeling was unreliable using these methods, progress was made toward understanding habitat limitations.

ACKNOWLEDGEMENTS

I'd like to thank everyone who has assisted me in one way or another throughout the duration of my thesis research, including Barbara Wilson, Chuck Bitting, C. D. Scott, Terra Fondriest, and Tony Collins with the Buffalo National River; Mark Baron with the Arkansas Game and Fish Commission; Eric Hearth and Leah Markum who assisted with field work; Jennifer Ogle from the University of Arkansas herbarium; Theo Witsell of the Arkansas Natural Heritage Commission; and my committee members Dr. Steve Stephenson, Dr. Johnnie Gentry, Dr. Kimberly Smith, and Dr. Gary Huxel. I would also like to thank Steve Mussmann for his patience and advice throughout the writing process.

TABLE OF CONTENTS

I. INTRODUCTION

Some species of plants are rare and others are widespread in their distribution, and a question might be asked as to why this is the case. Plants can be rare due to human-caused factors, such as over collecting, habitat fragmentation, and crowding out from the introduction of non-native species, but plants also can also be rare due to natural factors, such as endemism resulting from special habitat requirements or climate change (Kruckeberg and Rabinowitz 1985, Matthies 2004, Farnsworth and Ogurcak 2006, Damschen *et al.* 2010). Endemism, or restricted to a specific narrow, usually geographical range, can occur due to geographic isolation where evolutionary processes happen independently and also can occur due to uncommon abiotic factors in unique ecosystems (Robison and Smith 1982, Kruckeberg and Rabinowitz 1985). Neoendemic organisms are newly formed and have only recently undergone a speciation event (Stebbins and Major 1965, Kruckeberg and Rabinowitz 1985). It has been suggested that new species of plants have not yet fully dispersed into all possible suitable habitats, and that is the reason for their rarity (Lesica *et al.* 2006). Plants exhibit this regularly from hybridization, where two unique species of plants cross and create a new species of plant. Paleoendemic organisms are those that previously in time had a wider distribution but are now limited in their geographic range from factors such as changes in temperature or moisture availability (Stebbins and Major 1965, Kruckeberg and Rabinowitz 1985). It is well known that plants migrated during the Pleistocene epoch, a period in the Earth's history in which temperatures fluctuated greatly and forced plants to migrate to different locations as temperatures increased and decreased (Williams *et al.* 2001). Migration for plants requires time to allow for adaptation to new areas, and plant species became extinct during this last ice age, possibly because they were unable to adapt quickly enough to the changing climate or were lacking the features such as small seeds required to be carried long distances by the wind (Jackson and Weng 1999, Mildenhall and Byrami 2003).

Rare plants, whether they are rare from human or natural causes, are tracked by various organizations that maintain data on species occurrences. Plants and other organisms that are in danger of becoming extinct or are threatened are listed under the Endangered Species Act (ESA) passed by Congress in 1973 and are protected by the United States Fish and Wildlife Service (2004). The term "endangered species" is applied to species which are "in danger of extinction throughout all or a significant portion of its range" and the term "threatened" is defined as a "species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" as defined by the act (FWS 2004). As of May 18, 2013, 815 species of vascular plants (all species of plants other than mosses, liverworts, and hornworts) are listed as federally endangered or threatened according to the United States Fish and Wildlife Service. Certain criteria are required for federal protection under the ESA, and the ESA does not necessarily list all vascular plants that are in danger of becoming extinct (FWS 2004). Other organizations such as NatureServe, a non-profit organization that is a natural resources information data hub utilized by many state and federal agencies, also track organisms, including vascular plants, and give them a rank based on rarity. This ranking system utilized by NatureServe and state heritage commission organizations ranges from 1 (critically imperiled) to 5 (secure). The ranking system also utilizes a letter to indicate the area to which the ranking refers, such as G for a global scale and S for a state scale. There are currently 1,566 species of vascular plants located within the United States that are listed with NatureServe (2013) that are of global conservation concern with ranks of G1 (critically imperiled globally) through G3 (globally very rare and local throughout its range or found locally in a narrow range). This number is notably higher than the number of plants listed under the Endangered Species Act and doesn't include plant subspecies or varieties. The numbers listed for rare plants in each category are only estimates because it is exceedingly likely that not all species of plants have been discovered and classified.

Although multiple agencies maintain records on species occurrences and keep records on distribution data, sometimes there is little to no information on the habitat associated with the species record (USDA 2012, NatureServe 2013). In order to effectively search for possible new populations or to delimit potential habitats for tracked species of plants, at least some basic habitat information on the tolerance levels for abiotic factors and biotic associations of each species is needed.

The objective of this research was to characterize the habitat of two species of plants, *Delphinium newtonianum*, D.M. Moore and *Tradescantia ozarkana*, E.S. Anderson and Woodson, which are endemics in the Interior Highlands of the central United States (Figure 1.). The Arkansas Natural Heritage Commission (2013) and NatureServe (2013) list both species as G3 (globally rare or found in a restricted range) and S3 (statewide rare or uncommon), which gives them the title of narrow endemics. Characterization of the habitat was carried out through field data collection from known sites, and maps were created using ArcMap 10.1 to delimit potential habitat area utilizing data collected *in situ* and data extrapolated using ArcMap (ESRI 2012). Baseline data collected on individual population areas sampled during the research can serve as a guide for future studies and information found in this study can be used to draw conclusions for the cause of their rarity.

A. PLANT DESCRIPTIONS

Tradescantia ozarkana, commonly known as Ozark spiderwort, is a monocotyledonous

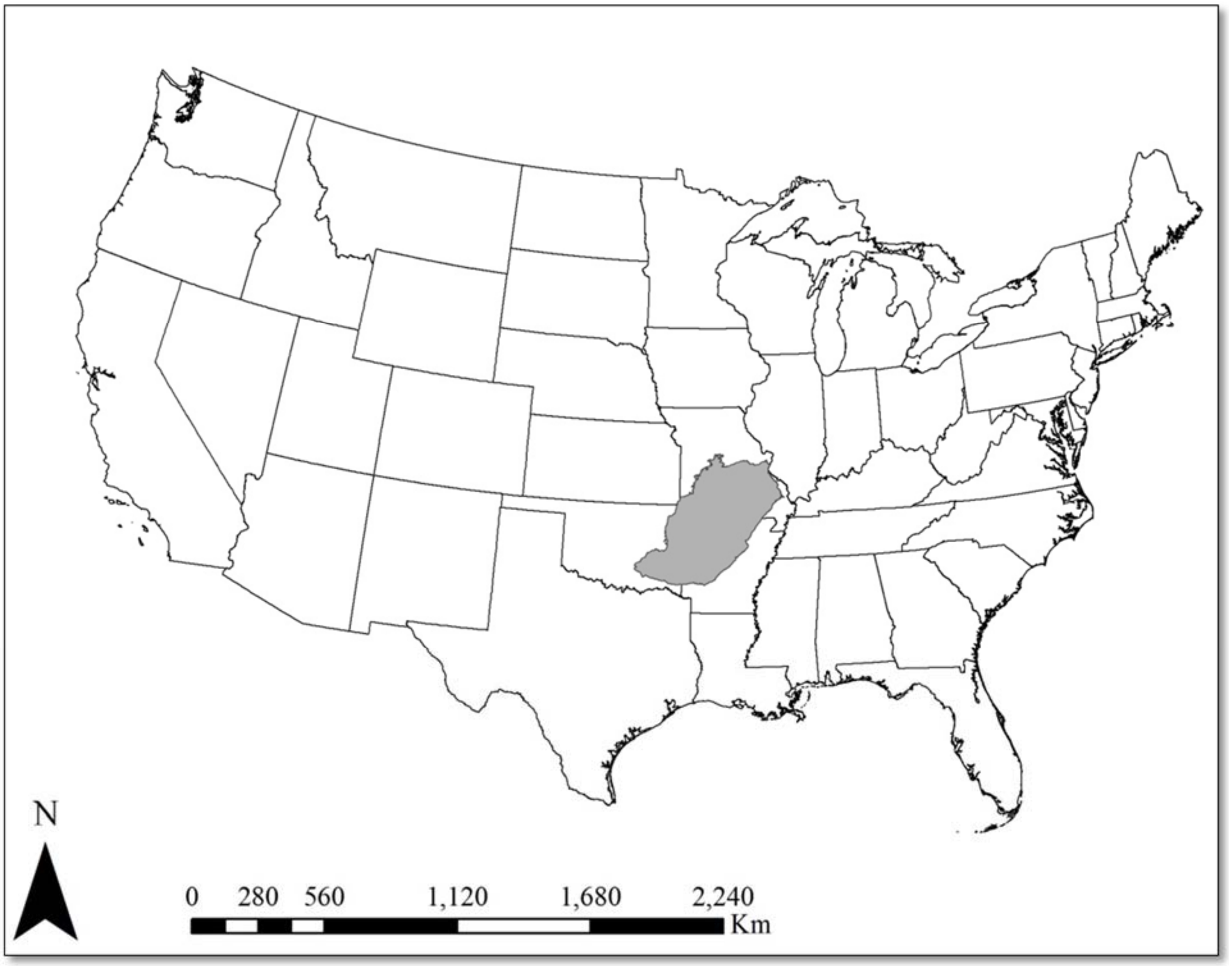

Figure 1. The location of the Interior Highlands of the central United States.

perennial plant and a member of the family Commelinaceae. The wide leaves that are discernibly wider than the sheaths and the glandular-stipitate hairs on the sepals make this species different from the approximately 69 other members of the genus *Tradescantia* (Anderson and Sax 1936, Steyermark 1963, Smith 1994) (Figure 2.). *Tradescantia ozarkana* is considered to be a member of the series *Virginianae*, which is endemic to North America (Hunt 1980). All members of the genus *Tradescantia* are restricted to North and South America.

Delphinium newtonianum D.M. Moore, commonly known as Moore's delphinium, Newton's larkspur or Ozark larkspur, is a dicotyledonous perennial plant and a member of the family Ranunculaceae. The most obvious unique characteristic of this species separating it from other North American species in the genus *Delphinium* is its cymose inflorescence (Smith 1994) (Figure 3.). Other species of *Delphinium* have indeterminate raceme inflorescences, meaning that the flowers do not mature from the terminal bud first as is the case for *D. newtonianum*. Members of the genus *Delphinium* can be found in Africa, Europe, Asia, and North America, and it is thought that the genus originated in the Himalayan region of Asia (Koontz *et al.* 2004).

B. DISTRIBUTION

The forests of the Interior Highlands also referred to as the Ozark/Ouachita-Appalachian forests, are a component of the eastern temperate forest region of the eastern United States (Figure 4.), and are comprised of various plant community types, including, but not limited to, savannah, several types of glades, woodlands, and closed-canopy forests (Braun 1947, Braun 1950). The Interior Highlands can be further divided into four ecoregions: the Ozark Highlands, Ouachita Mountains, Boston Mountains, and the Arkansas River Valley (Figure 5). These divisions are based on several factors, including soil, geology, and climate.

Tradescantia ozarkana populations can be found in three states: Arkansas, Missouri, and

Figure 2. Photograph of *Tradescantia ozarkana* taken 15 May 2011. The wide leaves are one of the characteristics that make this species unique. Photograph taken by Autumn Olsen at Kyles upper study site.

Figure 3. Photograph of *Delphinium newtonianum* taken on 15 Jun 2012. Partially mature capsules can be seen in the upper right. Photograph taken by Autumn Olsen at the Buck Ridge study site.

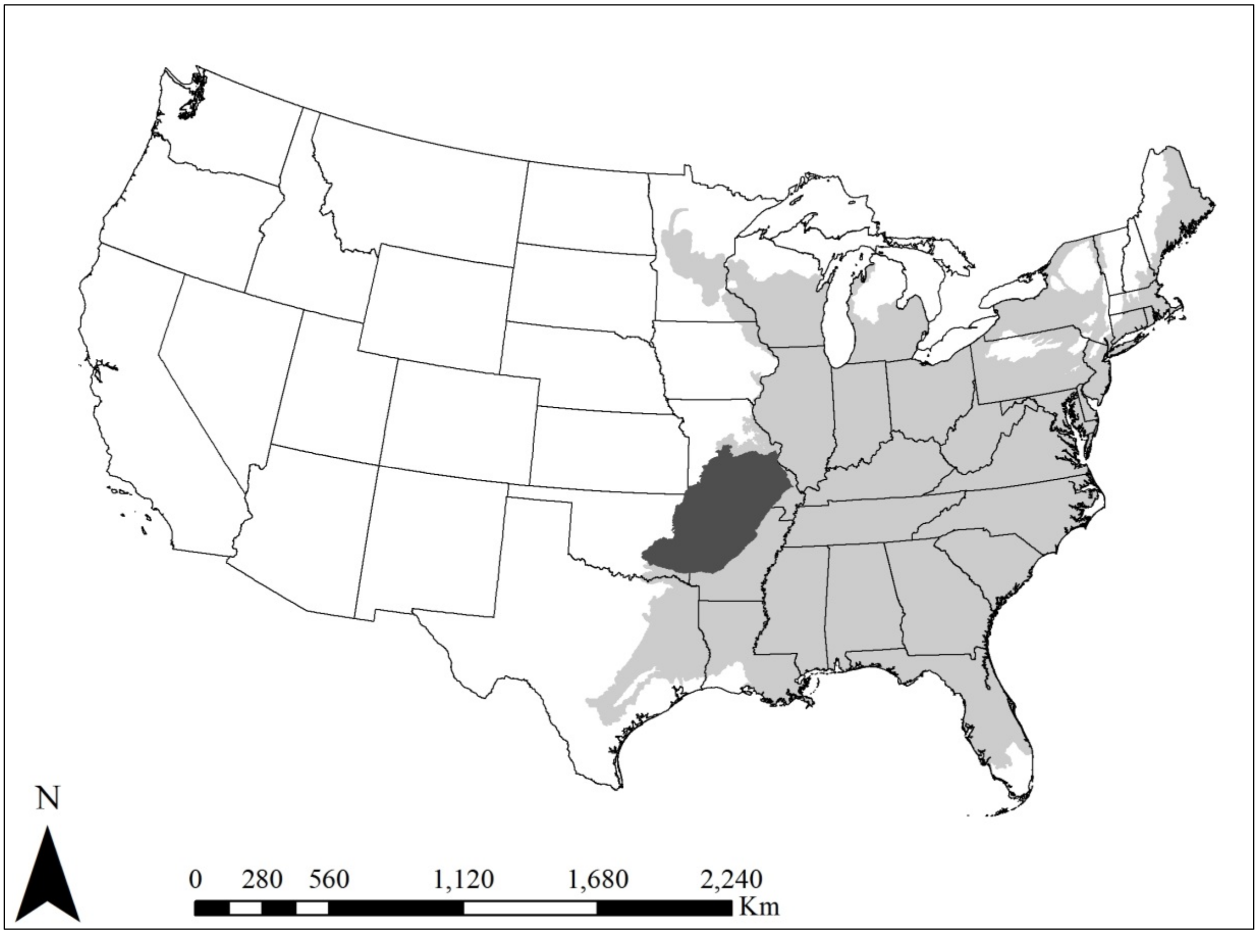

Figure 4. Map of the contiguous United States that shows the extent of the eastern temperate forest (level I) in light grey and the Ozark/Ouachita/Appalachian forest (level II), also known as the Interior Highlands, in dark grey.

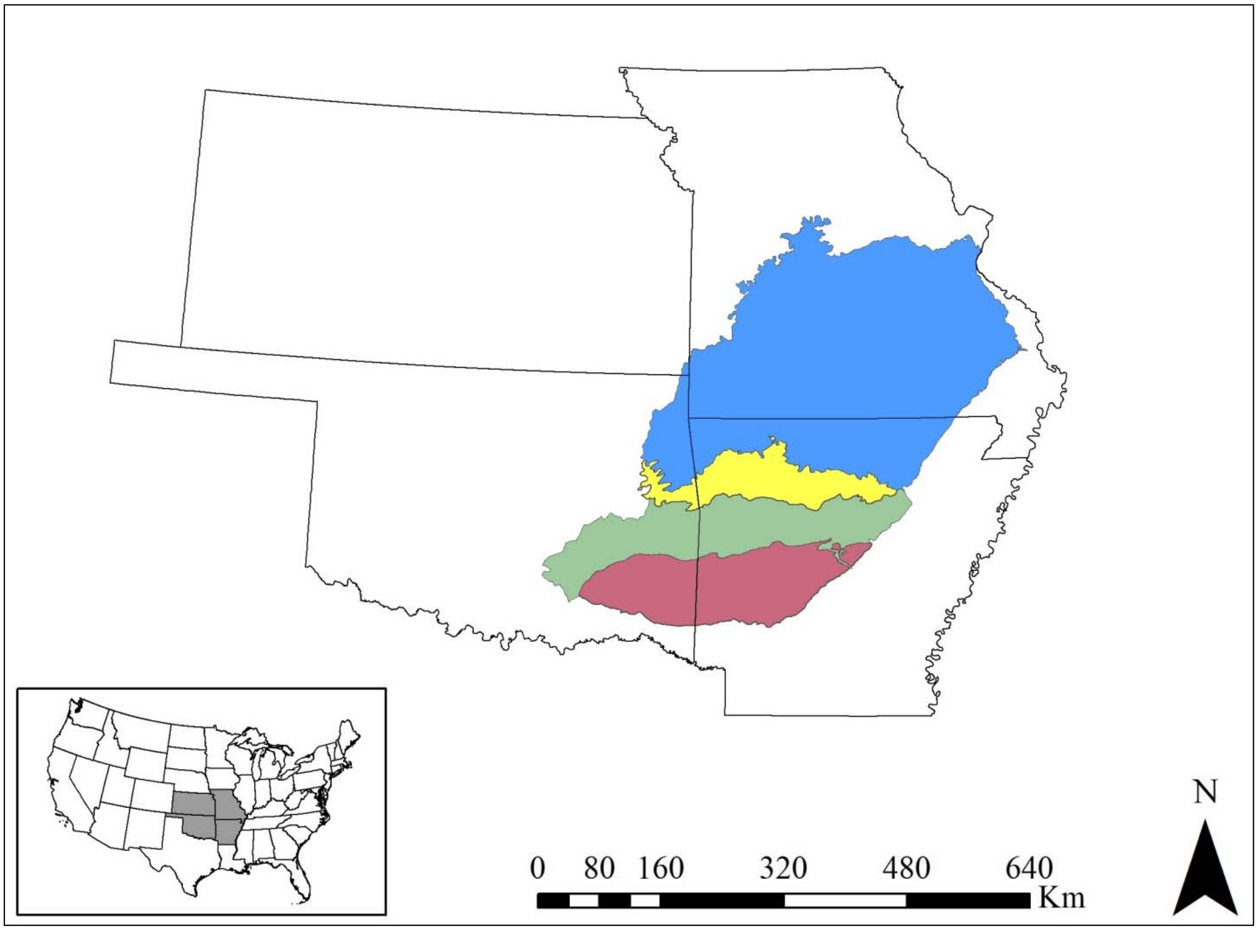

Figure 5. Map of the ecoregion divisions (level 3) of the Interior Highlands within Arkansas, Kansas, Missouri, and Oklahoma. The inset shows the location of these four states within the contiguous United States. Note: blue is the Ozark Highlands, yellow is the Boston Mountains, green is the Arkansas Valley, and pink is the Ouachita Mountains.

Oklahoma. The species is limited to seven southwestern Missouri counties, eighteen scattered counties throughout the western half of Arkansas, and nine of the most eastern counties in Oklahoma (Figure 6.) thus spanning all four ecoregions of the Interior Highlands, although only a limited number of populations occur in the Arkansas River Valley (Oklahoma Natural Heritage Inventory 2013, Arkansas Natural Heritage Commission 2013, NatureServe 2013, Witsell 2013).

Delphinium newtonianum has a more restricted range than *Tradescantia ozarkana*, occurring in only eight counties within the political boundaries of Arkansas (Figure 7.) (Arkansas Natural Heritage Commission 2013, NatureServe 2013). Pike, Pope, and Montgomery counties, which occur within the Ouachita Mountains ecoregion, are considered disjunct from the populations occurring in Johnson, Newton, Polk, Searcy and Van Buren counties located in the Boston Mountains and Ozark Highlands, due to the distance between them (Hardcastle and Gentry 2009).

Historical descriptions of the Interior Highlands indicate that the vegetation structure was different than what it is today, and that fires were a frequent occurrence prior to the arrival of Europeans to the region (Schoolcraft 1821, Swallow 1859). The fires would have prevented large tracts of land from becoming climax communities, and the forests probably would have been a patchwork of plant communities at different levels of succession, a situation that allowed many different plant species to thrive. Many studies, especially dendrochronology studies, indicate that fire was previously an important component of the Interior Highlands ecosystems and fire in the landscape today can be beneficial (Dey and Hartman 2005, Jenkins and Jenkins 2006, Stambaugh and Guyette 2006).

C. STUDY AREA

Due to time constraints, study sites were limited to Newton and Searcy counties. All

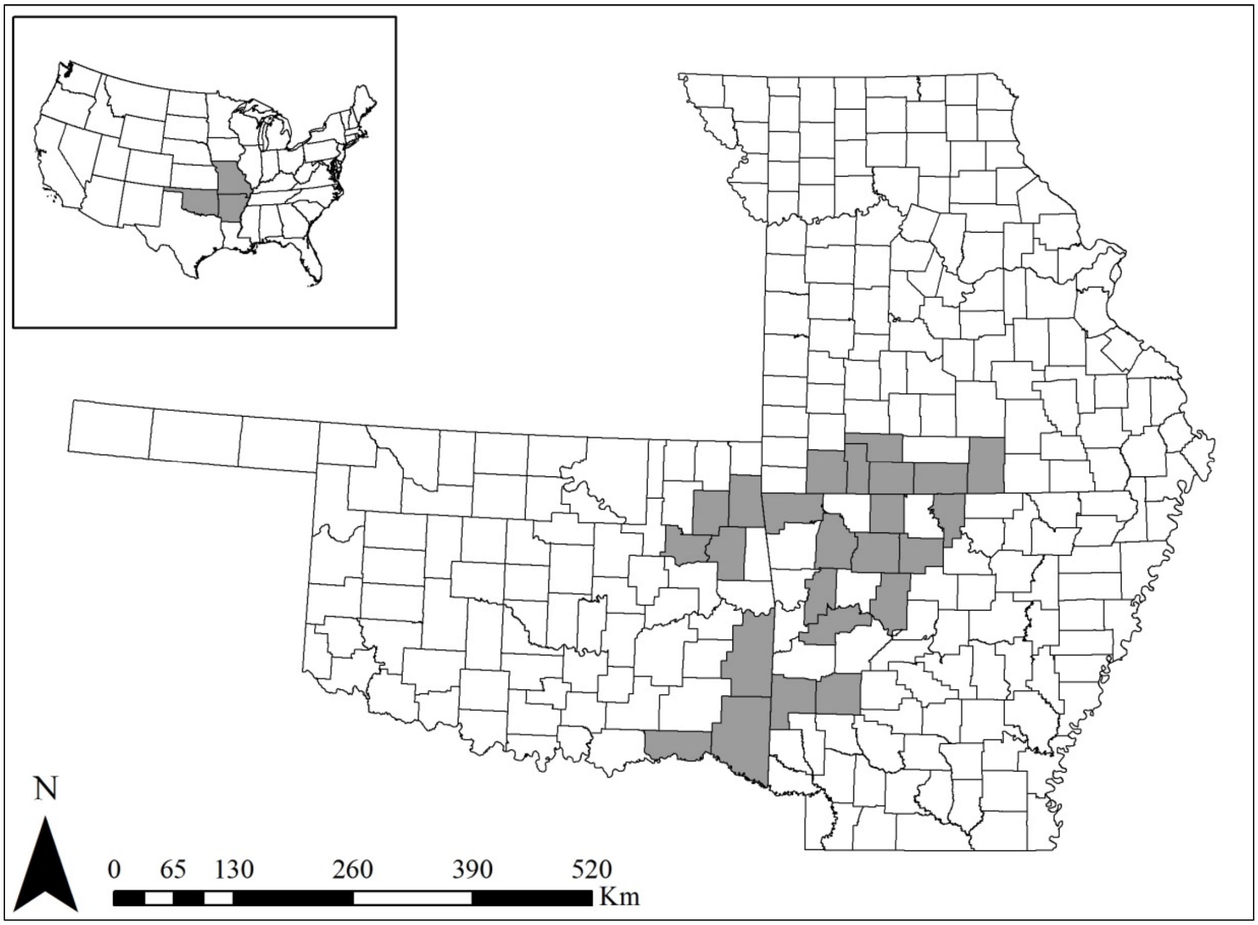

Figure 6. *Tradescantia ozarkana* county distribution within Arkansas, Missouri, and Oklahoma. The inset shows the location of Arkansas, Missouri, and Oklahoma within the contiguous United States.

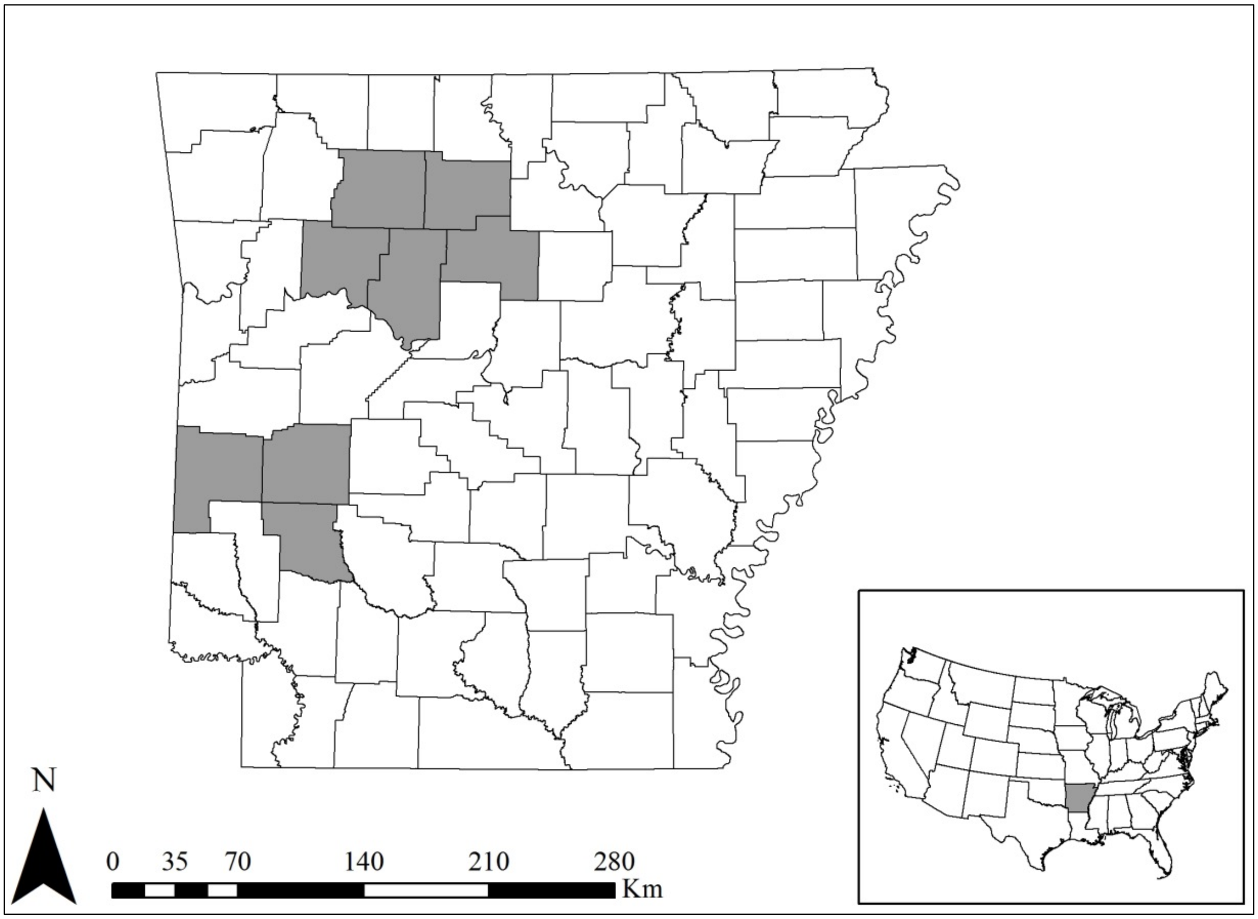

Figure 7. *Delphinium newtonianum* county distribution in Arkansas. The inset shows the location of Arkansas within the contiguous United States.

Ozark spiderwort study sites were located within the upper Boston Mountain physiographic subsection (ecoregion level IV) of the Boston Mountains (ecoregion level III) (Figure 8.) and Moore's delphinium study sites were located in both the upper Boston Mountains and the dissected Springfield Plateau-Elk River Hills (ecoregion level IV) of the Ozark Highlands (ecoregion level III) (Figure 9.). Each study site was assigned a number for reference purposes (Table 1.). Ozark spiderwort site numbers 1 through 4, 7, and 8 as well as all Moore's delphinium sites are located within the Buffalo National River National Park, a part of the National Park System. Ozark spiderwort site numbers 5 and 6 are both located on private land owned by Debbie and the late Cleve Clayton in Boone County, Arkansas.

D. CLIMATE

Mean daily temperatures for Newton and Searcy counties in Arkansas are between 0 and 2 degrees Celsius in January and between 24 to 26 degrees Celsius in July. The coldest month is January, with mean daily temperatures ranging from -4 to -3 degrees Celsius, and the hottest month is July, with mean daily temperatures ranging from 31 to 33 degrees Celsius. The date of the last spring freeze is about April 20, and the first fall freeze is around October 20, leaving approximately 180 days that are frost free throughout the year. On average, 106 to 127 cm of precipitation occurs annually, with May being the wettest month, with approximately 14 cm of rain. The driest month is January and precipitation averages from 6 to 11 cm in the form of rain and/or snow. In July of 2011, there was a moderate drought for the area of interest and in July of 2012 there was an exceptional drought according to the United States drought monitor archives maintained by the USDA (2013). Climate statistics for the city of Harrison in Arkansas indicate that the summers of both 2011 and 2012 had four record high temperatures (National Weather Service 2013). Other records were broken in 2011 and 2012, including the second wettest

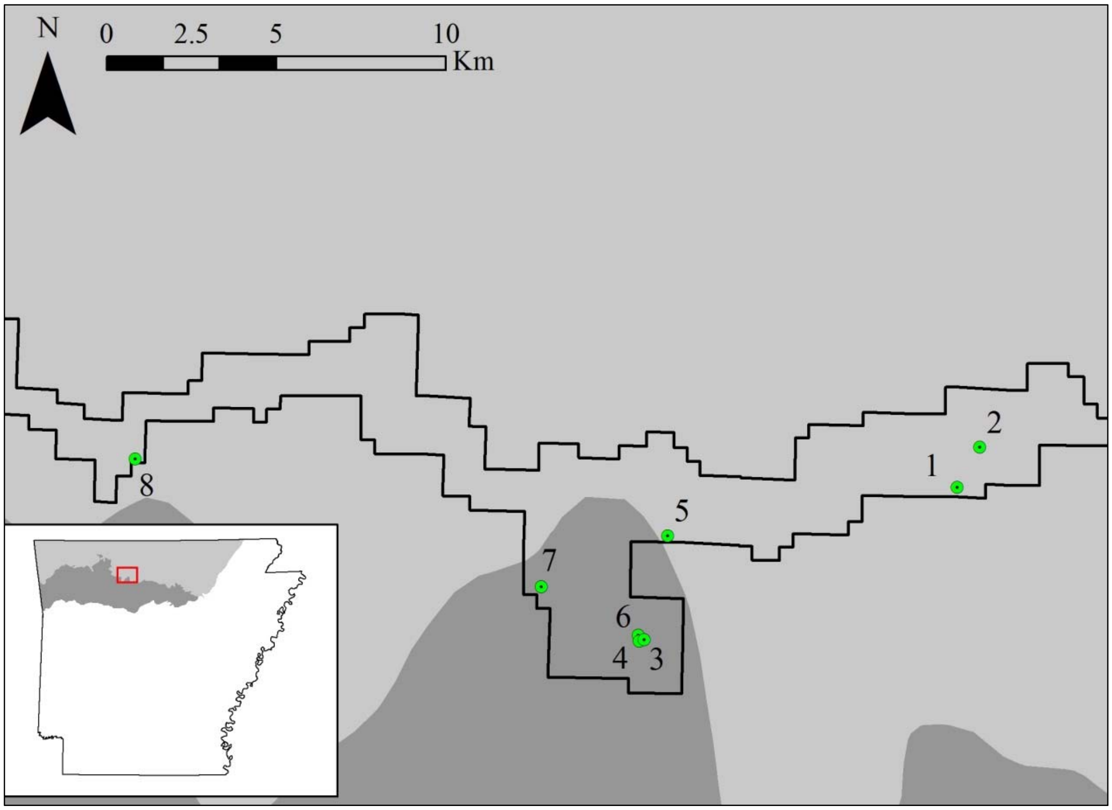

Figure 8. Location of *Tradescantia ozarkana* study sites in the Boston Mountains. Each number corresponds to the number given for each study site in Table 1. The black boundary is the boundary of the Buffalo National River. Inset is the state of Arkansas with the Boston Mountains in dark grey and the Ozark Highlands in light grey.

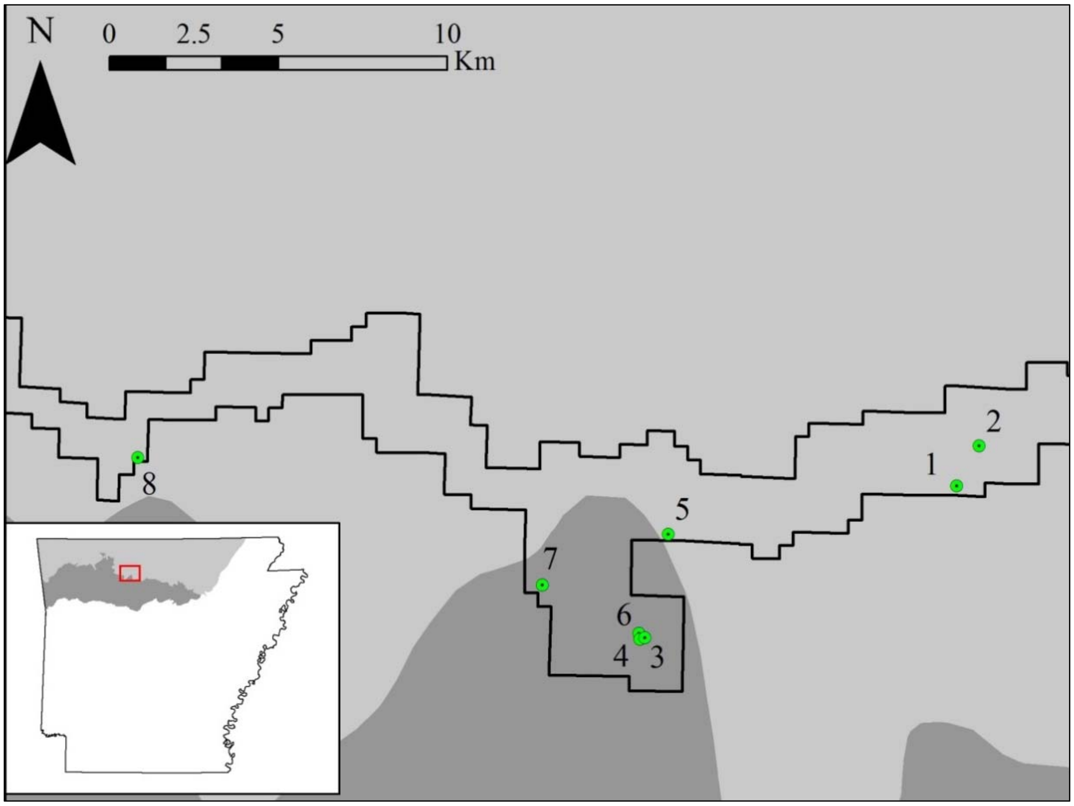

Figure 9. Location of *Delphinium newtonianum* study sites in the Boston Mountains and Ozark Highlands. Each number corresponds to the number given for each study site in Table 1. The black boundary is the boundary of the Buffalo National River. Inset shows the state of Arkansas with the Boston Mountains in dark grey and the Ozark Highlands in light grey.

Table 1. Study site name along with the assigned number and the date each was sampled. The aspect of each site was recorded from the center of the site. Direction indicates the cardinal direction from the center of each site.

Species	Site name	Date(s)	Number	Aspect (Direction)
Delphinium newtonianum	Gene Rush	19 - Jun - 12	8	290° (W)
	Woolum	21 - Jun - 12	7	level
	Dave Manes Bluff	18 - Jun - 12	6	level
	Point Peter north	27 - Jun - 11; 14 - Jun - 12	5	232° (SW)
	Point Peter south	23 - Jun - 11; 13 - Jun - 12	4	240° (SW)
	Point Peter unburned	20 – Jun - 12; 28 - Jun - 11	3	280 ° (W)
	Buck Ridge	24 - Jun - 11; 15 - Jun - 12	2	270° (W)
	Calf Creek	18 - Jun - 11; 11 - Jun - 12	1	270 ° (W)
Tradescantia ozarkana	Centerpoint lower	14 - Apr - 12	8	90 ° (E)
	Centerpoint upper	14 - Apr - 12	7	130° (SE)
	Red Fern lower	14 - May - 11; 6 - Apr - 12	6	40 ° (NE)
	Red Fern upper	18 - May - 12	5	30° (NE)
	Kyles lower	22 - Apr - 12	4	10° (NE)
	Kyles upper	15 - May - 11; 9 - Apr - 12	3	0° (N)
	Highway 43 lower	21 - Apr - 11; 7 - Apr - 12	2	230° (SW)
	Highway 43 upper	8 - Apr - 12	1	240° (SW)

spring in 2011, and both 2011 and 2012 were in the top ten hottest summers ever recorded (Skiles 1981, National Weather Service 2013).

E. GEOLOGY AND SOILS

The substrate that anchors terrestrial plants is as important as the climate in which the plant occurs (Beilmann and Brenner 1951). The upper Boston Mountains have steep, rugged slopes and rise to a maximum elevation of approximately 825 meters. They are characterized by a base of Pennsylvanian age sandstone and shale, with sandy and loamy components (Foti 1998). The Springfield Plateau has deep valleys, with a maximum elevation of approximately 425 meters and is characterized by having a Mississippian age limestone base with chert and clay components (Foti 1998).

Ozark spiderwort sites considered in this study were located on the Nella-Steprock-Mountainburg (very stony to cobbly loam), Nella-Steprock (stony to cobbly loam), and the Enders-Nella complexes (stony or gravelly loam) (Fowlkes *et al.* 1987, Laurent *et al.* 1992). Moore's delphinium sites were found on the Arkana-Moko (very cherty, very stony), Noark very cherty silt loam, Clarksville very cherty silt loam, Nella-Steprock-Mountainberg (very stony, stony, or gravelly loamy soil), Nella stony loam, Moko-Rock outcrop complex (stony silt loam in first 10 cm with limestone outcroppings), and Healing silt loam, occasionally flooded complexes (flooded no more than every two years and only for a very brief period; surface to subsurface soil is silt loam) (Fowlkes *et al.* 1987, Laurent *et al.* 1992).

F. HABITAT MODELING

GIS (Geographic Information Systems) habit modeling is commonly used for regional and landscape scale habitat predictions for a variety of species (Dettmers and Bart 1999, Mann *et al.* 1999, Store and Jokimäki 2003, Bourg *et al.* 2005; Williams *et al.* 2009). Increasingly detailed layers for use in GIS are being created, and more are becoming available to the public free of charge. Habitat modeling using GIS is possible using only known presence data of a particular organism to delimit potential suitable habitat area and does not require absence data (Hirzel *et al.* 2002). The basics behind this type of modeling use a ranking system for each of the cells in a raster of a particular habitat variable as potential habitat or not potential habitat for an organism. GIS habitat models have been successful through the process of intersecting multiple rasters and extracting cells with commonality without prior statistical analysis (Mann *et al.* 1999).

II. MATERIALS AND METHODS

A. FIELD DATA COLLECTION

During the 2011 and 2012 spring and summer field seasons, eight localities supporting populations of Ozark spiderwort and eight localities supporting populations of Moore's delphinium were sampled to assess the ecological habitat of both species. In 2011, Ozark spiderwort study site numbers 1 through 4 were sampled from 30 April to 21 May, and Moore's delphinium study site numbers 1 through 5 were sampled from 18 June to 28 June. In 2012, the sites from the previous year were resampled, and additional Ozark spiderwort study site numbers 5 through 8 were sampled and Moore's delphinium study site numbers 6 through 8 were sampled. The sampling dates in 2012 for Ozark spiderwort took place from 7 April to 18 May, and the sampling dates in 2012 for Moore's delphinium occurred 11 June to 21 June.

The sampling design for Ozark spiderwort populations 1 through 3 consisted of locating representative areas and establishing line transects directed outward in each cardinal direction from the approximate center of each representative area. Transects continued until a natural break, such as a stream or bluff, occurred in the subpopulations or if no plants were found to occur within 10 meters. Sampling design for the remainder of the Ozark spiderwort populations, numbers 4 through 8, and all of the Moore's delphinium populations involved locating the approximate center of representative area, and from this point, line transects were established in the four cardinal directions for 25 meters in each direction. Study sites that were sampled twice were sampled utilizing the same design.

A handheld GPS unit was used to obtain the latitude, longitude, and approximate elevation at the transect junction in the center of each study site. The aspect was also recorded from this location with a compass and was labeled as meter 0. Percent slope was measured, using a clinometer, from three different locations within each study site. A 1 by 1 meter vegetation square sampling frame was used, beginning at meter 0 and then placed at five meter intervals, along the transects to define areas for sampling.

When a population was initially sampled, the Daubenmire cover class method (Daubenmire, 1959) was used to estimate the percent cover of bryophytes, rocks, seedless vascular plants, graminoids, herbaceous plants, and woody plants ≤1.0 meter in height in every 1 by 1 meter square along the transects. When the species of interest, Ozark spiderwort or Moore's delphinium, fell within the 1 by 1 meter sampling square, each stem was numbered and its height was measured from the ground to the highest point on the plant. The number of stems in each plant grouping for plants located within the subplots was also recorded for Ozark spiderwort study sites in 2012.

All species of vascular plants other than woody plants ≥1.0 meter in height within the sampling square were recorded; unknown species were collected and later identified. Nomenclature for plant taxa follows Kartesz (2013). Tree species with a height of more than 1.0 meter as well as the dominant tree species for each study site were annotated during a walk taken through each study area.

In 2011, reproductive structures were counted for Ozark spiderwort numbered plants by classifying them into three categories: buds, flowers, and fruits. In 2012, a category was added to distinguish between mature and immature fruits. Definitions of the reproductive structures for Ozark spiderwort were as follows: flowers had a part of a petal visible, buds had no part of a petal visible, immature fruits had decomposing petals and no visible ovary, and mature fruits had a visible ovary. The numbered plants for Moore's delphinium had two categories for reproductive structure counts: buds/flowers and fruits. Ozark spiderwort mature fruits were collected only from the uppermost inflorescence of a stem and from only one stem per plant grouping. The number of mature fruits collected per site varied and was based on the number of stems in the area. Moore's delphinium fruits were not collected due to the small number of individuals at each site.

Coarse woody debris data were also collected during the initial site surveys. Data were gathered along the transect tapes by recording the distance along the transect tapes where pieces of bark or wood one centimeter or larger in diameter intersected the tape. The percent coverage for each study site was found by adding the individual measurements where coarse woody debris intersected the transect tapes and dividing by 100 (Cox 1985).

During the 2012 field season, a digital photograph was taken of the canopy of each study site, except for Dave Manes Bluff and Centerpoint upper, with a 14 megapixel 5.0 x wide optical zoom Olympus Tough TG-610 camera. The digital photograph was taken from the center of meter zero from approximately one meter off the ground and pointed at zenith to extrapolate percent canopy cover using image processing software. Canopy cover for the purposes of this research was defined as any obstruction to the sky from the forest floor.

Also during the 2012 field season, four soil samples were collected from each study site. These samples were obtained from the center of each rectangle delimited by the transect meter tapes (Figure 10.) and placed in a plastic bag to create a composite sample. The soil collection was achieved by initially scraping off the outer humus layer and then collecting the soil beneath the layer to a depth of no more than seven centimeters. The soil was dried on newspaper, sifted with a 2 mm standard soil sieve, and then sent for analysis to the Brookside Soils Laboratory (New Knoxville, Ohio).

A. ANALYSES

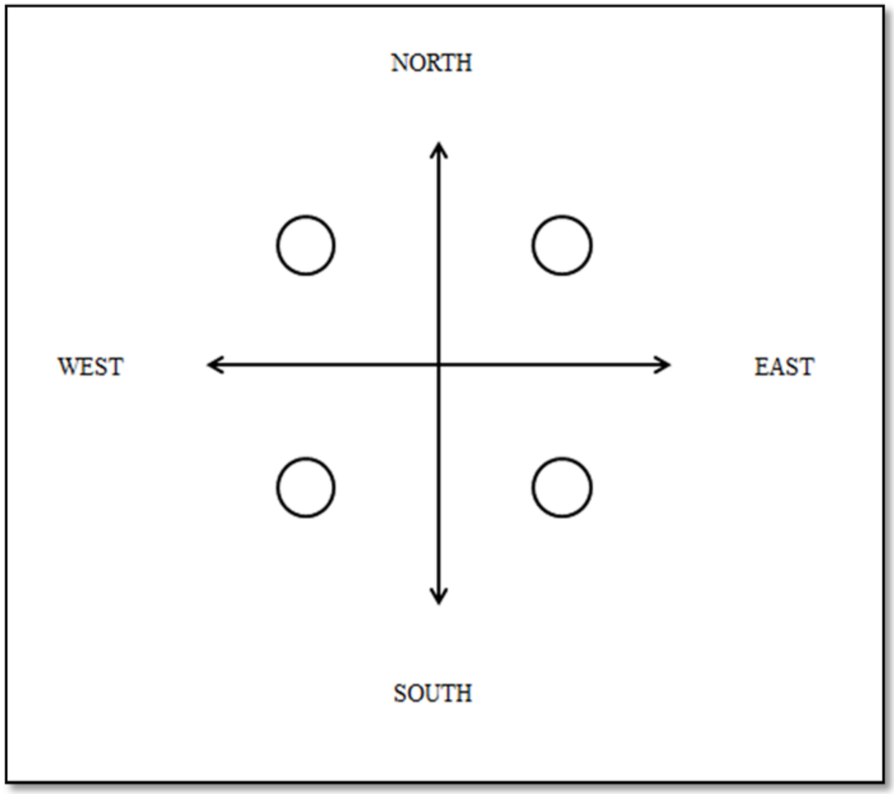

Figure 10. Graphical representation of soil sampling locations within each study area. The lines represent transect lines and the circles represent the approximate location within each study site where soil samples were collected from. Graphic is not drawn to scale.

The three percent slope measurements from each study site were averaged together to get an overall estimate of the percent slope for each study area. The average percent slope for all Ozark spiderwort study sites was then calculated, along with the standard deviation, to obtain an overall percent slope. The same calculations were also calculated for Moore's delphinium study sites.

Averages of each category of cover class for each study site were found by converting the Daubenmire cover classes to the midpoints of each class and then taking the average of the total midpoints for each category. The mean and standard deviation were also derived for each category across all study sites for each species. The mean and standard deviation for coarse woody debris coverage were also calculated for an overall average for Ozark spiderwort and Moore's delphinium study sites. For soil data, the averages and standard deviations of each soil parameter were calculated and minimum, maximum, and median values were reported for Ozark spiderwort and Moore's delphinium study sites.

The average number of plants per sampling square was found by taking the number of plants sampled per site and dividing this by the total number of sampling squares per site. The estimated number of plant stems per site was obtained by taking the mean number of plants per sampling square and multiplying by the total area of the sampling site. It was noted that if there was an increase or decrease in the estimated number of plant stems per study sites for those sites sampled consecutively for two years. The percent change was calculated for sites that had a change in the estimated number of plants over the course of the two years.

F-tests were first conducted to test for equal variances to determine the appropriate t-test. Unpaired t-tests were conducted for study sites that were sampled for two consecutive years using plant counts in each sampling square to determine if there was a significant change in the number of stems for each location. Paired t-tests were also conducted using the total number of stems per study site for the first year and the total number of stems for the second year for each species to determine if there was a significant difference in the stems per year for each species.

To estimate percent canopy cover, the digital images taken of the canopy were uploaded into ArcMap 10.1 and iso cluster unsupervised classification was applied to each image using default settings and eight classes (Figure 11.) (ESRI 2012). The reclassify tool was then used to manually classify the eight class images to two classes: canopy cover and sky (Figure 12. upper). The output rasters' attribute tables were used to determine the percent canopy cover by dividing the number of pixels that were classified as canopy by the total number of pixels in each image. A signature was created using the original digital images and the two class rasters as the feature sample data. Maximum likelihood classification was performed utilizing the signatures and the original digital images to determine the probability of correct classification of pixels in the canopy cover and sky raster (Figure 12. lower).

PC-ORD version 4.34 was used to calculate dissimilarity values among all study sites of *D. newtonianum* and *T. ozarkana* using plant species identified at each study site (McCune and Mefford 1999). Euclidean distances were used to determine the similarity/dissimilarity between each site using presence/absence of species. Taxa not identified to species level were not included in the analysis except for genera unique to an individual study site.

JMP PRO 11 was used for principal components analyses (PCA) and factor analyses using physical and soil parameters independently for both species (SAS Institute Inc. 2013). For factor analyses, oblimin rotation, an oblique rotation, was applied to all factor analyses to maximize/minimize the loading of each variable on the individual factors. Selected principal components (PC) and factors were then plotted against the estimated stem densities for each study site in linear regressions. ANOVAs were conducted to determine any significant correlations between factors or components and stem densities.

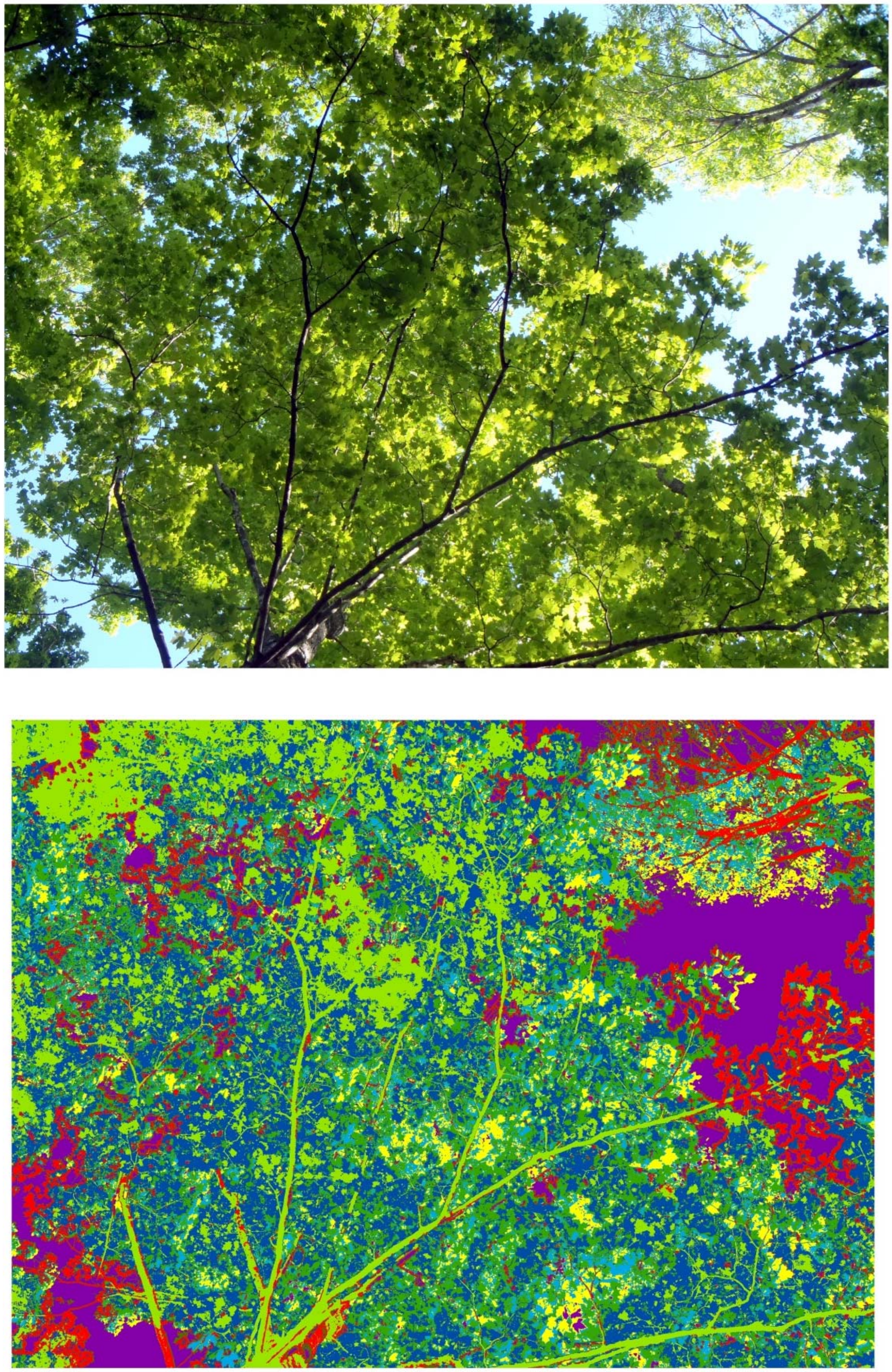

Figure 11. Upper half shows an example of a digital image of the canopy obtained for percent canopy cover. Photograph was taken by Autumn Olsen on 7 April, 2012 at the Highway 43 lower study site. Lower half is the same image after iso cluster unsupervised classification.

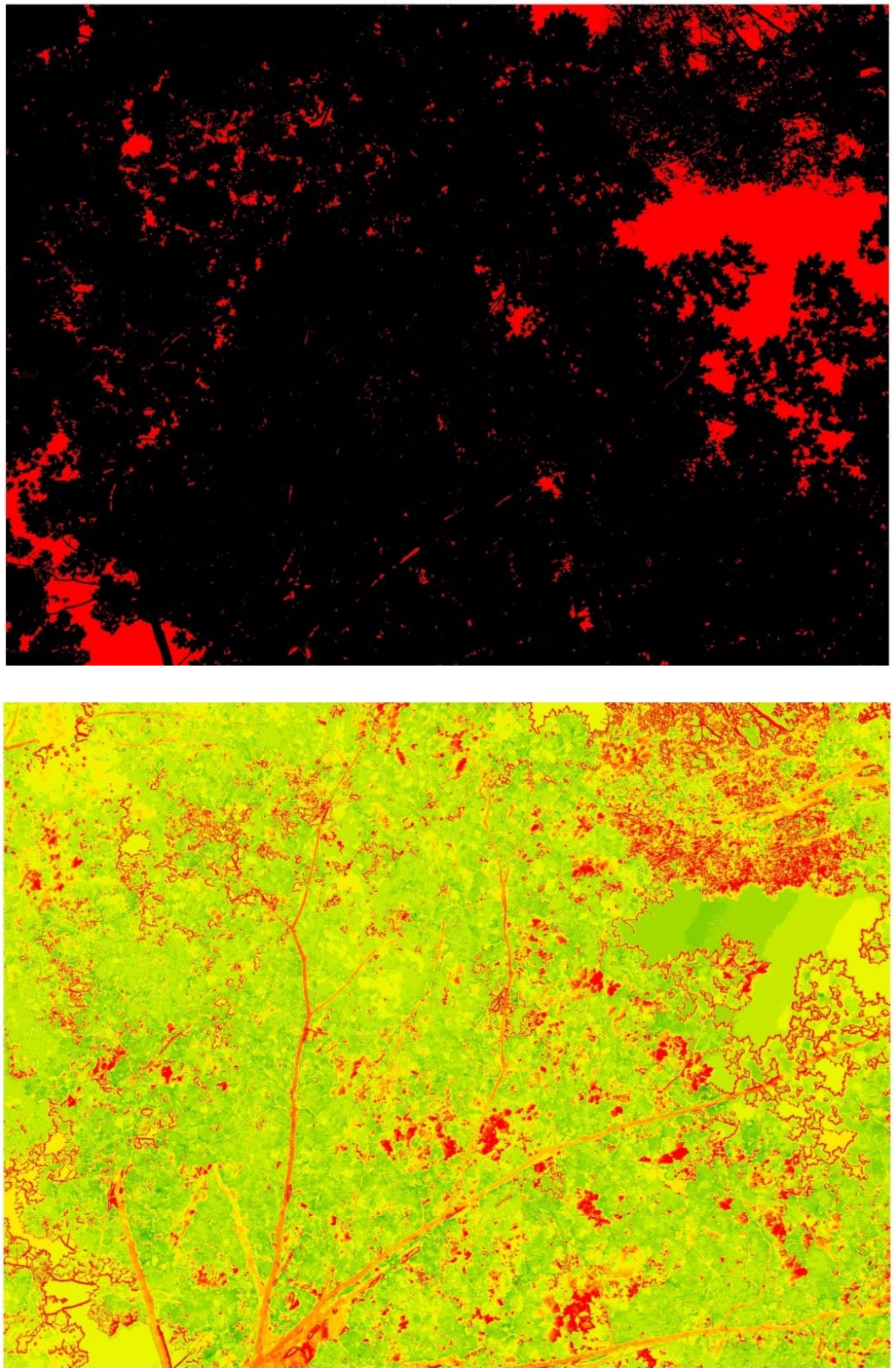

Figure 12. Upper half shows a two class raster that was reclassified from the iso unsupervised classification image. Black represents canopy and red represents sky. Bottom half is the confidence raster output. Green areas have highest probability of being correctly classified, yellow areas have an average probability of being correctly classified, and red areas have the lowest probability of being correctly classified. Note many areas in red are branches and incorrect classification would not affect canopy cover percentages.

C. HABITAT MODELING

For habitat modeling, all data were downloaded from Geostor (2014) other than site location data. Study site location data were collected with a GPS from the center of each study site and additional point location data of species occurrences were obtained from the Arkansas Natural Heritage Commission (2011). ArcGIS 10.1 (ESRI 2012) was used for data processing. The study site locations were inspected for accuracy on a 1:24,000 topographical map in ArcMap. A 25 meter buffer was applied to the point location shapefiles and the feature envelope to polygon tool was then used to transform the circular buffers to square buffers (Figure 13.). The buffers for the *T. ozarkana* sites that were not 2500 m² (Red Fern lower, Kyles upper, Highway 43 lower) were edited to represent the area sampled for those study sites. The square buffers were then checked for proper location on the topographical map and were moved using the editor tool bar, if necessary, to insure the most precise location.

A polygon layer of Arkansas' ecoregions was inserted into ArcMap. The select tool was used to select the following level IV ecoregions: upper Boston Mountains, lower Boston Mountains, Springfield Plateau, dissected Springfield Plateau-Elk River Hills, and White River Hills (Figure 14.). The Central Plateau, Arkansas Valley, and Ouachita Mountain level IV ecoregions were not included in order to decrease the amount of data in the model. Arkansas' public land polygon layer was also inserted into the ArcMap data frame, and the select tool was utilized to select only wilderness areas, national forests, and national parks. A polygon shape file was created around Red Fern upper and Red Fern lower *T. ozarkana* study sites in order to include data from these sites, which are located on private land. This private land polygon was then merged with the public land polygon to create a polygon of the area of interest (Figure 15.). This newly created polygon shape file was then clipped by the selected ecoregions.

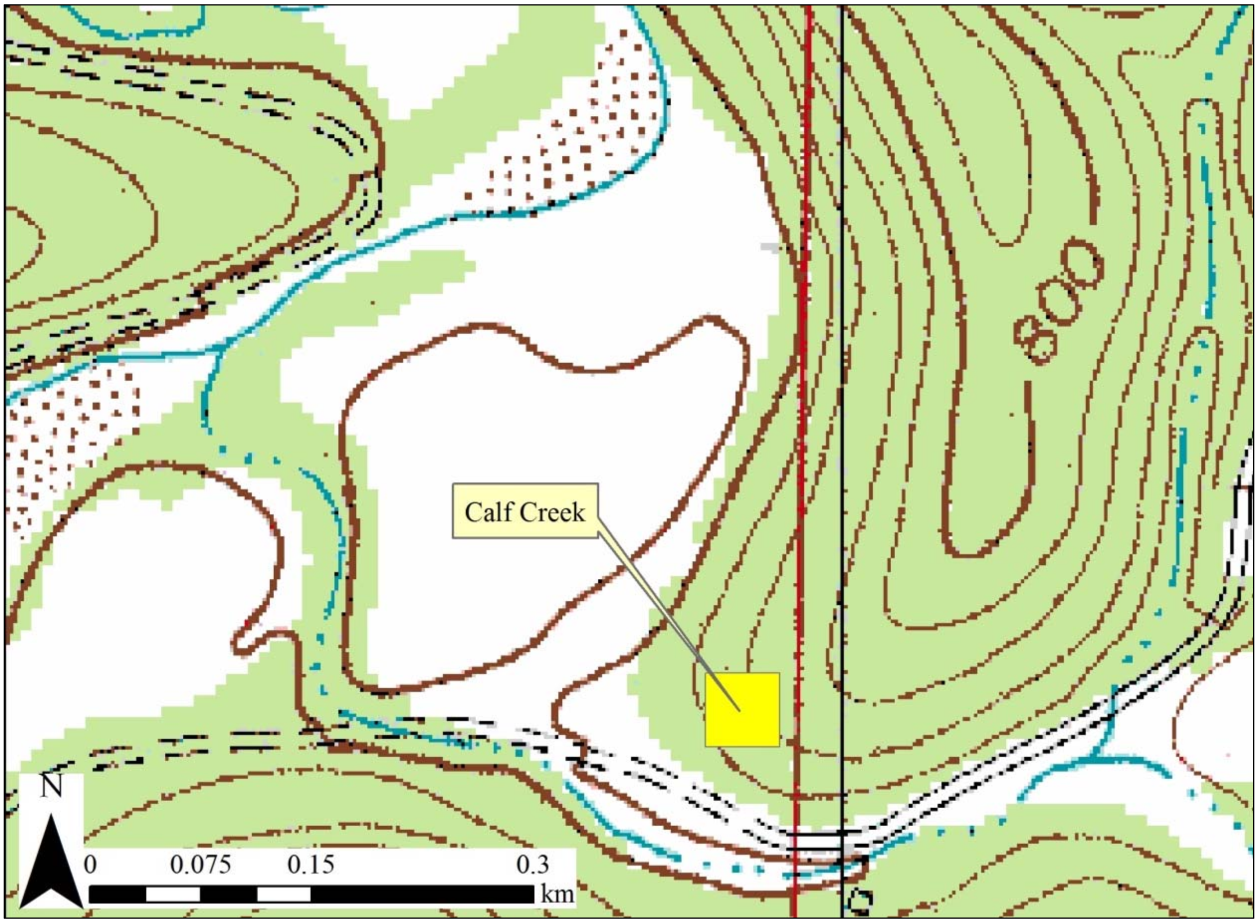

Figure 13. Example of square buffer representing the Calf Creek study area (2500 m²) on a 1:24,000 topographical map.

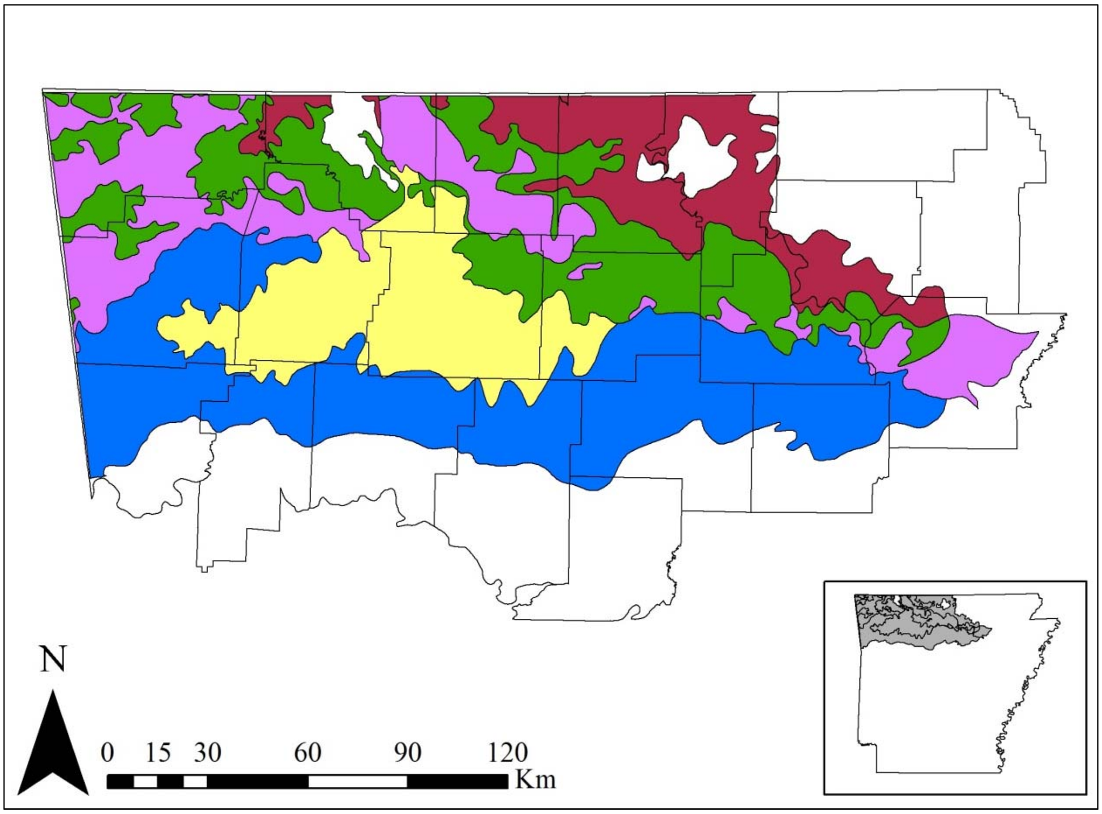

Figure 14. Selected Arkansas level IV ecoregions used in habitat modeling over county boundaries. Inset shows overall area of ecoregions within the state of Arkansas. Note: yellow is the Upper Boston Mountains, blue is the Lower Boston Mountains, purple is the Springfield Plateau, pink is the White River Hills, and green is the Dissected Springfield Plateau-Elk River Hills.

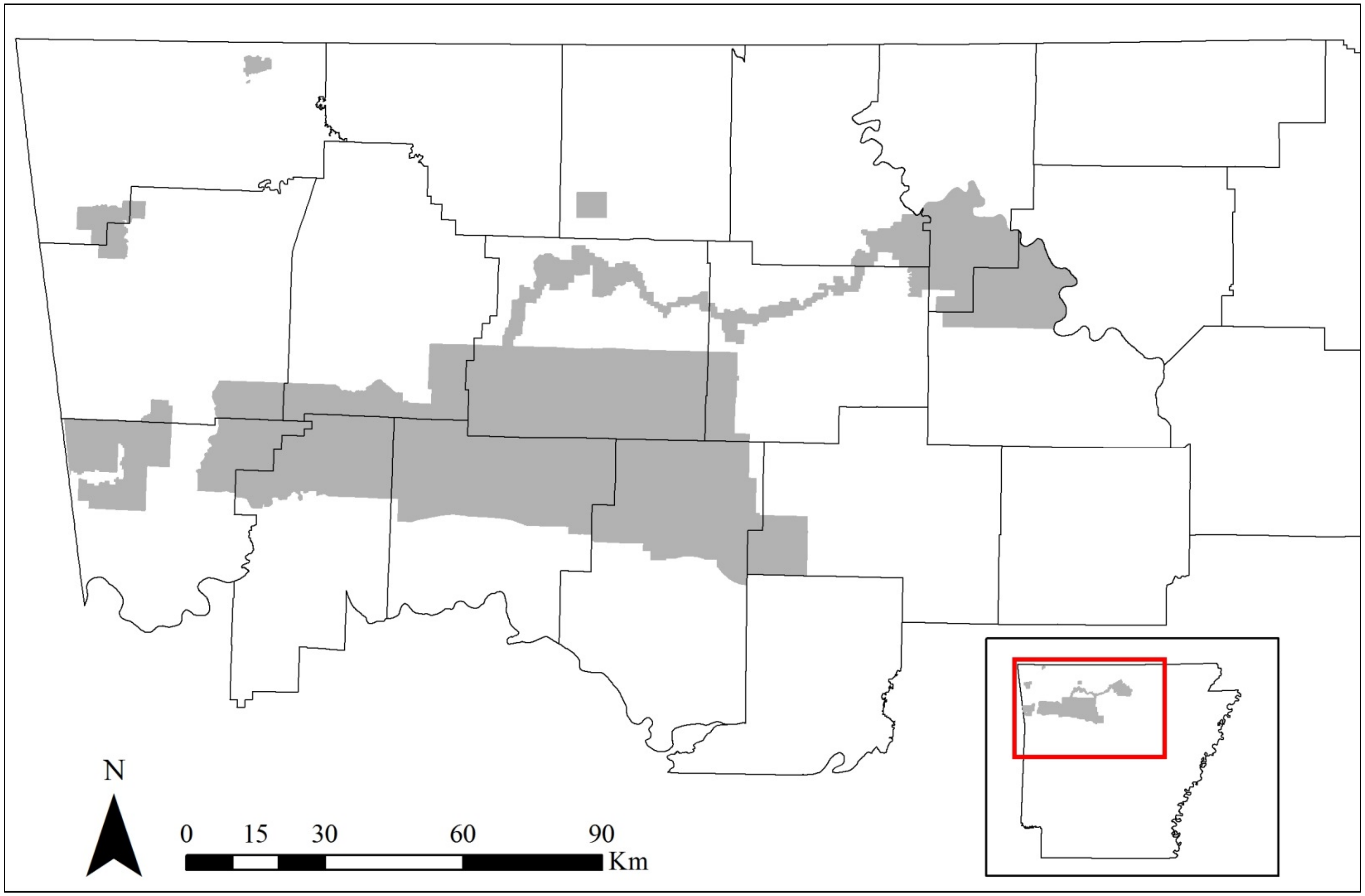

Figure 15. Map of the selected area of interest including the created buffer area around Red Fern lower and Red Fern upper study sites located on private land in Boone County. Inset shows the area of interest within the state of Arkansas.

Five meter digital elevation models (DEM) for all Arkansas counties (Baxter, Benton, Boone, Conway, Crawford, Franklin, Izard, Johnson, Madison, Marion, Newton, Pope, Searcy, Stone, and Van Buren) covered by the area of interest polygon were added to ArcMap's data frame. The extract by mask tool was used to extract only the area of interest from the DEMs. The individual DEMs were then combined using the mosaic to raster tool.

The slope and aspect tools were applied to the DEM of the area of interest, and the newly created slope and aspect rasters were reclassified for data extraction. The reclassified aspect raster contained 10 classes to correspond to general directions (northeast, south) or to no direction (flat). The reclassified slope raster was classified to 12 classes. Classes 1 - 10 represented slopes from 0% to 50% in 5% increments (class 1 ranged from 0% - 5% slope, class 2 ranged from 6 to 10% slope, etc.). Class 11 represented slopes from 50% - 60% and class 12 represented slopes 60% and above. The DEM was also reclassified to 20 classes with each class representing approximately 15 meters. A soils polygon layer and a geology polygon layer were uploaded, clipped to the area of interest, and transformed to rasters.

The study site square polygons were used as feature data in the extract by mask tool using the slope, aspect, elevation, geology, and soil rasters as the input rasters. The data extracted from each raster layer for each study site were then compiled for each species. These data were used to extract only the particular slopes, aspects, elevations, geology, and soils types in which the species were known to occur. The reclassified elevation, slope, and aspect rasters, as well as the geology and soils rasters of the area of interest, were then selected to only contain the values from the data extraction. These rasters were then reclassified to contain only 1 class (yes = 1; no = 0 or no data) and then input to the raster calculator using the Boolean operator "&" between each raster layer. This created a single raster made of only those cells which were common to all

5 raster layers. Twelve known locations each of *D. newtonianum* and *T. ozarkana* received from the Arkansas Natural Heritage Commission (2011) that were located within the area interest were uploaded to ArcMap, converted to rasters with a cell size of 5, and used as feature data in the extract by mask tool using the respective habitat model raster for each species as the raster input to determine the validity of the models.

Due to the output of the initial model for *T. ozarkana*, the following expansion model was only completed for *D. newtonianum*. The 12 known point locations of *D. newtonianum* used for testing the initial model were transformed to rasters with a cell size of 5. The extract by mask tool was applied using the 12 rasters as feature data on the reclassified elevation, slope, and aspect rasters, as well as on the soil and geology rasters of the area of interest. The data extracted using the 12 rasters were compiled with the data from the original 8 study sites and the select by attributes tool using this data was used on the rasters of the area of interest. The output rasters were each reclassified to contain 1 class (yes = 1; no = 0 or no data) and then put in the raster calculator and the Boolean operator “&” used. This output a model in which all the selected data had to be present in a particular cell to be considered potential habitat. Forty-eight new point locations for *D. newtonianum* were uploaded to ArcMap and converted to a raster with a cell size of 5. The extract by mask tool was used using the new location rasters as feature data on the projected potential habitat to determine how many of the new locations fell within the model.

For *T. ozarkana*, a second habitat model was created using the data extracted from the reclassified elevation, aspect, and slope rasters using the entire area of each study site as feature data. This allowed for examination of the number of pixels that were of a particular class in each of the rasters. The frequencies of the number of pixels associated with each class were then used to rank the classes of each raster into 3 groups. The 3 groups, each with an associated cell value were: good (1), better (2), and best (3). The rankings (values) of each class were then used to reclassify the elevation, aspect, and slope rasters and then added together (+) in the raster calculator to output a raster of the area of interest with cell values from 2 to 9. Twelve point locations of known *T. ozarkana* presence were used to test the validity of the model which required the same data transformations and tools to extrapolate the cell value of the 12 sites.

A third model for both *T. ozarkana* and *D. newtonianum* was created using 20 points (eight study sites, 12 sites placed in initial models for validation) and only the slope, aspect, and elevation rasters. Only point data from the original eight` study sites was used rather than the entire study area. The 20 points (individual rasters with a cell size of 5) were used as feature data once more in the extract by mask tool using the reclassified slope, aspect, and elevation rasters. Data from the 20 locations were examined to identify the frequency of each raster class. The frequencies were then used to rank the classes of each raster into 3 groups, with each group having an associated cell value: good (1), better (2), and best (3). The values were then used to rank each class in the reclassified slope, aspect, and elevation rasters of the total area of interest. All three rasters of the area of interest were then added together (+) using the raster calculator tool to output a single raster with potential habit ranging from 0 (not potential habitat) to 9 (best possible potential habitat). All potential combinations of 2 added rasters of the area of interest were also added together to output rasters with values from 0 – 6 to determine if one of the parameters was more important than another.

To test the validity of the third model, 48 point locations for *D. newtonianum* and 22 point locations for *T. ozarkana* not previously used were uploaded and transformed into 5 cell sized rasters. The new locations were used as feature data in the extract by mask tool on the projected habitat rasters to extract each site’s projected habitat raster value.

III. RESULTS

A. PLANT LOCALITIES

Elevation ranges, averages, and standard deviations along with slope ranges, averages and standard deviations for *D. newtonianum* and *T. ozarkana* localities are found in Table 2. The slope average for both species was found to be the same at 14%. The aspect of each site can be found on Table 1. *Delphinium newtonianum* sites have a general westerly aspect, ranging from 232° - 290°.

B. SOILS

Median, mean, and standard deviation values for soil parameters are reported in Table 3. for *D. newtonianum* and in Table 4. for *T. ozarkana*. *Tradescantia ozarkana* soil pH values ranged from slightly acidic at a low of 6.1 to near neutral at 7.1. More variation was found for *D. newtonianum* soils that ranged from a slightly acidic soil (pH = 6.2) to a slightly alkaline soil (pH = 7.5). The average percent organic matter for *D. newtonianum* was only slightly higher than that for *T. ozarkana*, with values of 6.7 and 7.9, respectively. *Delphinium newtonianum* study sites contributing to the higher average percent organic matter included Dave Manes Bluff, Gene Rush, and Woolum, each having individual measurements of ≥9.0% (Appendix A.). Average calcium measurements for *D. newtonianum* sites (ppm = 3210) were higher than those for *T. ozarkana* sites (ppm = 2157), contributing to the alkalinity of the *D. newtonianum* soils. Magnesium averages also differed between *T. ozarkana* and *D. newtonianum*. The magnesium mean for *T. ozarkana* sites was higher than the mean for *D.* newtonianum sites, with values of 227 ppm and 146 ppm, respectively. Soil parameter values can be found in Appendix B.

C. COVERAGE

Percent coverage values for coarse woody debris at each site as well as mean and

Table 2. Summary data for all *Delphinium newtonianum* and *Tradescantia ozarkana* study sites. Note: Each site had three slope readings that were averaged to obtain average percent slope. SD = standard deviation.

Species	**Dates Sampled**	**Number of Sites**	**Elevation Range (m)**	**Elevation Avg (m)**	**Elevation (StDev)**	**Slope Range (%)**	**Slope Avg (%)**	**Slope (StDev)**
Delphinium newtonianum	11 Jun - 21 Jun 2012	8	194 - 547	366	159.5	0 - 28	14	± 7.6
Tradescantia ozarkana	7 Apr - 18 May 2012	8	424 - 633	542	74.6	0 - 30	14	± 8.2

Table 3. Values of soil parameters recorded for *Delphinium newtonianum* study sites (n = 8). Note: lb/A = pounds per acre, ME/100g = milliequivalents of hydrogen per 100 grams of soil, and H_20 1:1 = 1 part soil to 1 part distilled water.

Parameter	**Minimum value**	**Median value**	**Maximum value**	**Mean value**	**Standard deviation**
Total exchange capacity (ME/100g)	11.7	19.9	22.8	19.4	± 4.4
pH (H_20 1:1)	6.2	6.7	7.5	6.8	± 0.5
Organic matter (%)	5.5	8.3	10.7	7.9	± 1.9
Estimated nitrogen release (lb/A)	102	117	125	114	± 9
Calcium (ppm)	1531	3253	4090	3210	± 920
Magnesium (ppm)	98	153	182	146	± 36
Potassium (ppm)	124	152	181	154	± 19
Sodium (ppm)	14	21	37	21	± 8
Sulfur (ppm)	8	9	11	9	± 1
Phosphorus (ppm)	10	35	45	31	± 13
Boron (ppm)	0.7	1.1	6.4	1.8	± 1.9
Iron (ppm)	59	80	135	86	± 22
Manganese (ppm)	33	183	148	205	± 58
Copper (ppm)	1.5	2.0	3.6	2.1	± 0.7
Zinc (ppm)	2.5	5.0	7.0	5.0	± 1.3
Aluminum (ppm)	286	466	775	465	± 147

Table 4. Values of soil parameters recorded for *Tradescantia ozarkana* study sites (n = 8). Note: lb/A = pounds per acre, ME/100g = milliequivalents of hydrogen per 100 grams of soil, and H_20 1:1 = 1 part soil to 1 part distilled water.

Parameter	**Minimum value**	**Median value**	**Maximum value**	**Mean value**	**Standard deviation**
Total exchange capacity (ME/100g)	13.2	14.5	22.0	15.2	± 3.1
pH (H_20 1:1)	6.1	6.6	7.1	6.6	± 0.3
Organic matter (%)	5.3	6.7	7.7	6.7	± 1.0
Estimated nitrogen release (lb/A)	102	108	117	109	± 5
Calcium (ppm)	1591	2155	2721	2157	± 415
Magnesium (ppm)	171	211	402	227	± 86
Potassium (ppm)	116	152	404	177	± 94
Sodium (ppm)	20	21	510	84	± 172
Sulfur (ppm)	7	10	14	10	± 2
Phosphorus (ppm)	14	22	41	24	± 10
Boron (ppm)	0.5	0.9	5.0	1.5	± 1.5
Iron (ppm)	48	63	123	73	± 25
Manganese (ppm)	147	307	401	288	± 89
Copper (ppm)	1.0	2.9	7.7	3.3	± 2.0
Zinc (ppm)	2.9	5.1	10.6	5.7	± 2.5
Aluminum (ppm)	457	525	826	574	± 124

standard deviation values for each species are found in Table 5. Point Peter unburned had the highest coarse woody debris coverage of *D. newtonianum* sites at 4.5%, and Centerpoint lower had the highest coarse woody debris coverage of *T. ozarkana* sites at 6.2%. The average percent cover values for selected plant types and rocky ground cover for each site along with averages and standard deviations for each species are found in Table 6. *Tradescantia ozarkana* sites had a higher overall mean for percent cover of graminoids (8.3%) when compared to *D. newtonianum* sites (4.1%), but a lower overall mean for percent cover of herbaceous plants (34.8%) when compared to *D. newtonianum* sites (48.0%). Midpoint frequency histograms for plant and rock cover classes can be found in Figure 16. for *D. newtonianum* and Figure 17. for *T. ozarkana*. The most common midpoint for herbaceous percent cover for both species was 37.5. Although the mean percent cover of woody plants for *D. newtonianum* (11.6%) and *T. ozarkana* (11.9%) were similar, the most frequent midpoint differed between species with *D. newtonianum* at 15% woody plant cover and *T. ozarkana* at 2.5% woody plant cover. The percent canopy cover for each site (except Dave Manes Bluff and Centerpoint upper) is listed in Table 7. *Delphinium newtonianum* canopy cover ranged from 57.2% to 90.6% with a mean of 79.9% and a standard deviation = ± 13.1. *Tradescantia ozarkana* canopy cover ranged from 74.0% to 94.9% with a mean of 87.4 and a standard deviation = ± 5.1.

D. STEM DENSITY

Delphinium newtonianum site stem density estimates and associated data can be found in Table 8. The greatest number of stems sampled was at the Point Peter unburned study site in 2011 with 16 plants, and the lowest number of stems sampled was at Point Peter south in 2012 and Dave Manes Bluff in 2012 with zero plants sampled at both study sites. All sites that were sampled for two consecutive years had a decrease in the number of plants at each site. The

Table 5. Percent coverage of coarse woody debris coverage for each study site.

Species	Site name	Coarse woody debris coverage
Delphinium newtonianum	Gene Rush	1.4
	Woolum	2.1
	Dave Manes Bluff	1.2
	Point Peter north	3.1
	Point Peter south	2.9
	Point Peter unburned	4.5
	Buck Ridge	2.4
	Calf Creek	2.2
	Mean ± Standard deviation	2.5 ± 1.1
Tradescantia ozarkana	Centerpoint lower	6.2
	Centerpoint upper	2.8
	Red Fern lower	3.9
	Red Fern upper	4.3
	Kyles lower	4.4
	Kyles upper	1.7
	Highway 43 lower	4.1
	Highway 43 upper	5.4
	Mean ± Standard deviation	4.9 ± 1.4

Table 6. Average percent cover for selected plant types and rocky ground cover for each study site and average (n = 8) percent cover for each species. Cover classes were first estimated using the Daubenmire cover class method (1959) and the midpoint of each class was used for averaging. Note: @ is missing one sample from herbaceous plants; # is missing three samples from woody plants and two from herbaceous plants.

Species	**Site name**	**Total number of sampling squares**	**Rock**	**Bryophytes**	**Seedless vascular plants**	**Woody plants**	**Graminoids**	**Herbaceous plants**
Delphinium newtonianum	Gene Rush	21	39	21	0	7	6	32
	Woolum	21	23	19	5	5	2	34
	Dave Manes Bluff	20	3	2	0	7	5	55
	Point Peter north	21	12	3	0	15	7	72
	Point Peter south	21	12	3	0	11	4	54
	Point Peter unburned	21	0	1	0	18	1	58
	Buck Ridge	21	7	4	1	8	3	41
	Calf Creek	21	4	4	0	22	5	38
	Mean		12.5	7.1	0.8	11.6	4.1	48.0
	Standard deviation		± 12.9	± 8.0	± 1.8	± 6.1	± 2.0	± 13.9
Tradescantia ozarkana	Centerpoint lower	21	6	3	0	11	2	54
	Centerpoint upper	21	28	7	0	7	6	30
	Red Fern lower	30@	4	4	4	9	9	52
	Red Fern upper	21@	3	5	0	4	3	23
	Kyles lower	21	6	7	0	9	8	18
	Kyles upper	9	6	8	0	19	6	26
	Highway 43 lower	17#	15	6	0	23	21	37
	Highway 43 upper	21	4	3	0	13	11	38
	Mean		9.0	5.4	0.5	11.9	8.3	34.8
	Standard deviation		± 8.5	± 1.9	± 1.4	± 6.3	± 5.9	± 13

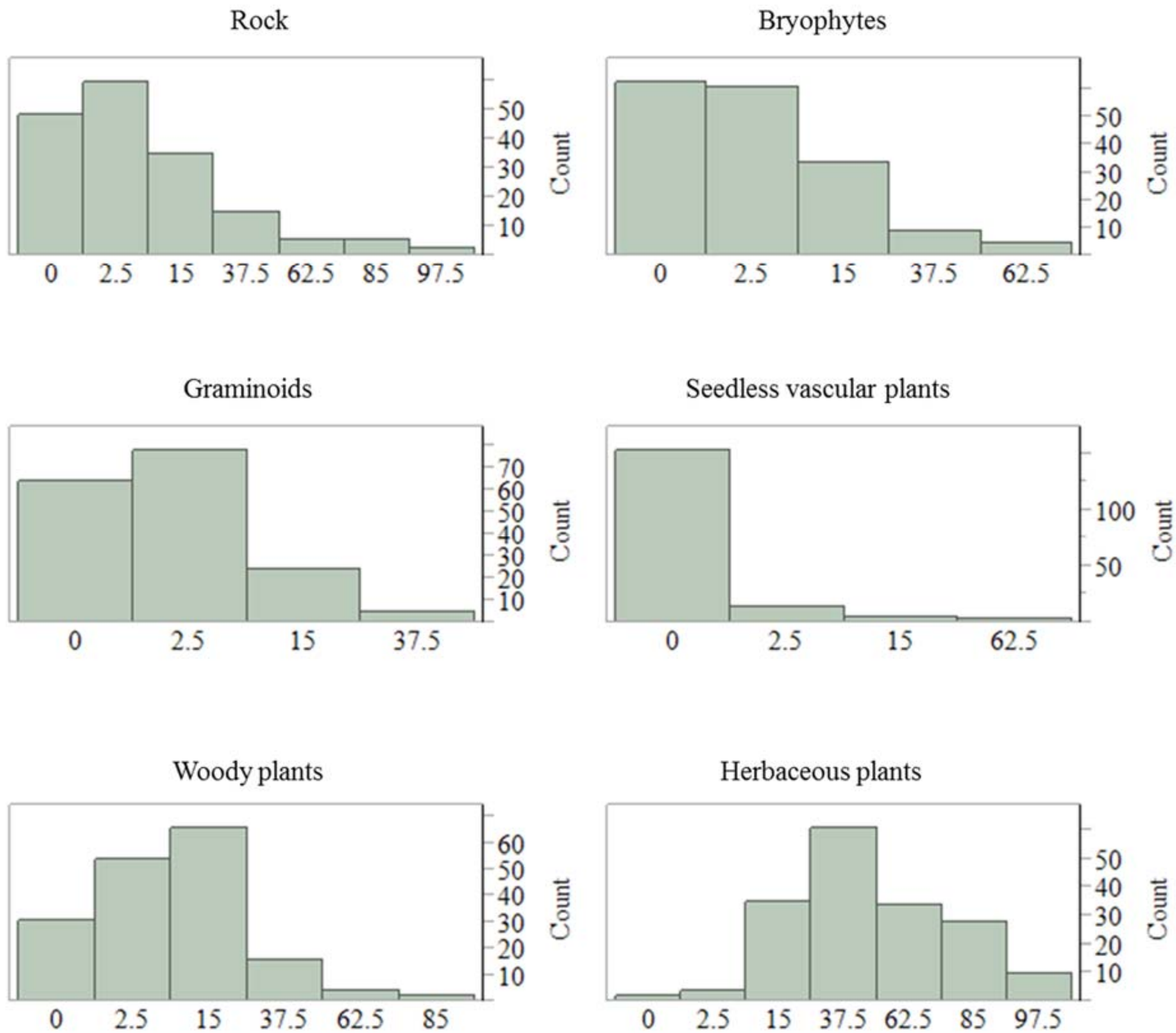

Figure 16. Histograms showing frequencies of Daubenmire cover class midpoints of selected plant types and rock for *Delphinium newtonianum*. Actual counts are listed above each bar.

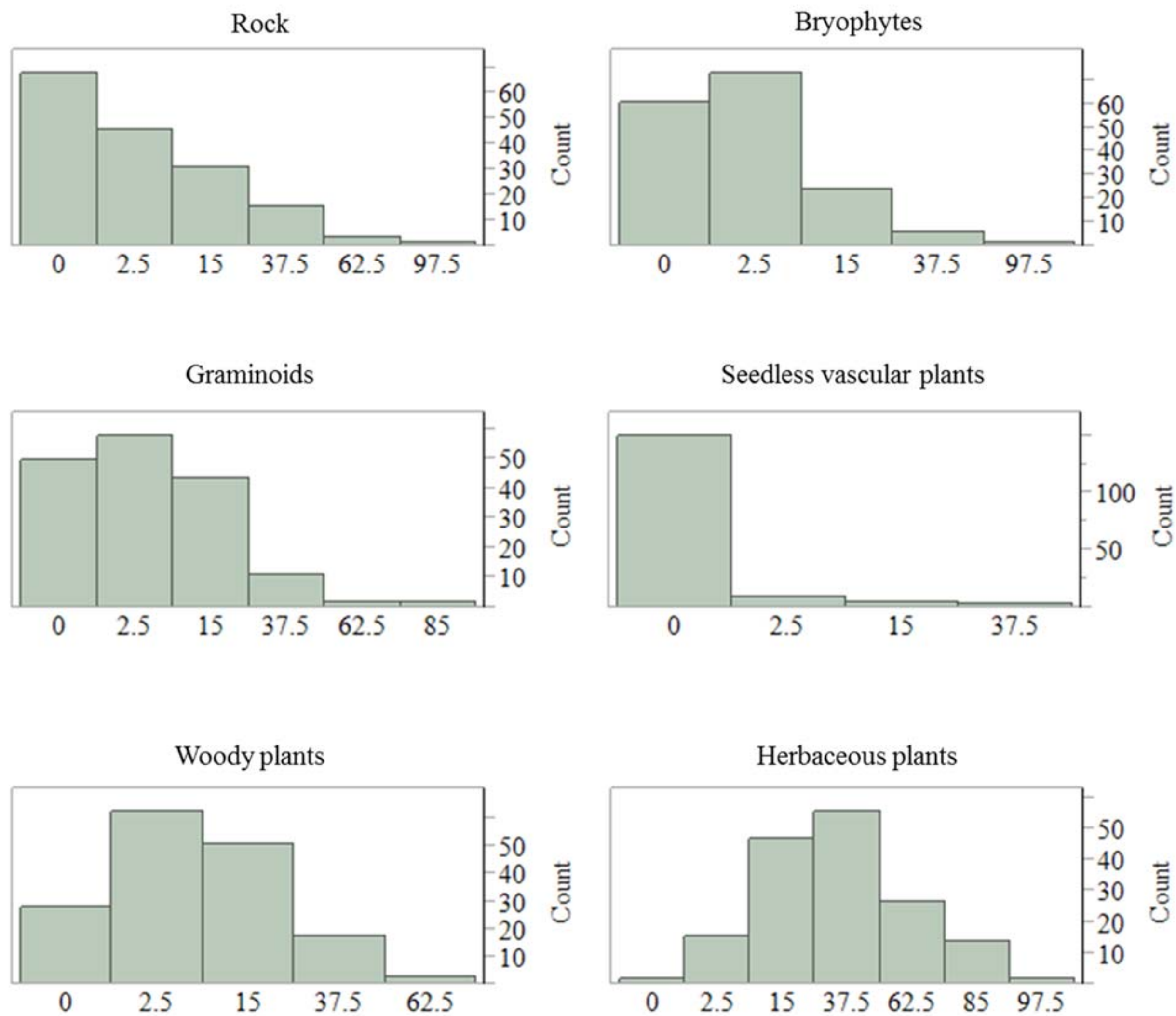

Figure 17. Histograms showing frequencies of Daubenmire cover class midpoints of selected plant types and rock for *Tradescantia ozarkana*. Actual counts are listed above each bar.

Table 7. Percent canopy cover for study sites as derived by the method described in the text. Probabilities listed are for the pixels being correctly classified as canopy or not canopy, using a maximum likelihood classification method. Note: ND = no data.

Species name	Site name	Canopy cover (%)	Probability ≥0.9 (%)	Probability ≥0.75 (%)	Probability ≤0.05
Delphinium newtonianum	Gene Rush	90.6	54.3	72.0	9.5
	Woolum	85.4	38.4	66.7	7.9
	Dave Manes Bluff	ND	ND	ND	ND
	Point Peter north	57.2	24.1	55.3	6.6
	Point Peter south	66.2	50.7	60.4	9.9
	Point Peter unburned	81.7	63.7	39.7	8.0
	Buck Ridge	88.0	54.0	73.3	8.9
	Calf Creek	90.4	43.5	70.5	8.0
	Mean	79.9			
	Standard deviation	± 13.1			
Tradescantia ozarkana	Centerpoint lower	81.9	45.9	70.3	8.3
	Centerpoint upper	ND	ND	ND	ND
	Red Fern lower	74.0	30.7	58	7.2
	Red Fern upper	94.9	50.2	74.2	8.2
	Kyles lower	86.6	49.4	74.1	8.2
	Kyles upper	89.9	54.5	71.2	10.6
	Highway 43 lower	89.6	56.7	73.4	10.6
	Highway 43 upper	81.7	45.7	66.5	9.0
	Mean	87.4			
	Standard deviation	± 5.1			

Table 8. Density of stems for *Delphinium newtonianum* study sites. Note: - is used to indicate a decrease in the number of stems; area of each study site = 2500 m^2

Site name	**Year**	**Number of plants sampled**	**Number of sampling squares**	**Mean number of plants per m^2**	**Estimated number of stems per site**	**Increase or decrease**	**Percent change**
Point Peter north	2011	7	21	0.3	208		
Point Peter north	2012	1	21	0.1	63	-	70
Point Peter south	2011	7	21	0.3	188		
Point Peter south	2012	0	21	0.0	0	-	100
Point Peter unburned	2011	16	21	0.8	500		
Point Peter unburned	2012	2	21	0.1	63	-	87
Buck Ridge	2011	11	21	0.5	313		
Buck Ridge	2012	1	21	0.1	63	-	80
Calf Creek	2011	12	21	0.6	375		
Calf Creek	2012	1	21	0.1	63	-	83
Gene Rush	2012	1	21	0.1	63		
Woolum	2012	5	21	0.2	125		
Dave Manes Bluff	2012	0	20	0.0	0		

highest percent change over a two year period was at Point Peter south with 100% change due to zero plants sampled in 2012. The least amount of change was at Point Peter north with a 70% change.

Delphinium newtonianum study sites that were sampled for two consecutive years (Buck Ridge, Calf Creek, Point Peter north, Point Peter south, and Point Peter unburned) were tested for significant differences ($P \leq 0.05$) between the 2011 and 2012 sampling square plant counts. Initial F-tests resulted in significant results requiring unpaired t-tests with unequal variances. T-tests were found to be significant for Point Peter unburned ($P = 0.036$, $df = 22$), and Calf Creek ($P = 0.032$, $df = 22$), but not for Point Peter south, Point Peter north, and Buck Ridge ($P > 0.05$). A paired t-test was also conducted for the combined number of plants from 2011 study sites and compared to the total number of plants from those same sites in 2012. The result was significant ($P = 0.003$, $df = 4$).

Tradescantia ozarkana study site stem density estimates and associated data can be found in Table 9. The greatest percent change over a two year period was at the Kyles upper site with a 66% change in the number of stems due to a decrease from 15 stems in 2011 to 5 stems in 2012. The other three sites (Highway 43 lower, Highway 43 upper, and Red Fern lower) sampled in both 2011 and 2012 had decreases in the total number of stems per site.

For *T. ozarkana* study sites that were sampled for two consecutive years, tests for significant differences ($P \leq 0.05$) between the 2011 and 2012 sampling square stem counts were calculated. F-tests were first used to test for equal variance. F-tests were not significant for any study site except Kyles upper. T-tests with equal variances for Highway 43 lower, Highway 43 upper, and Red Fern lower and a t-test with unequal variance for Kyles upper were not found to be significant ($P > 0.05$) for stem counts at any site. A paired t-test using total stem counts from

Table 9. Density of stems for *Tradescantia ozarkana* study sites. Note: - is used to indicate a decrease in the number of stems; + is used to indicate an increase in the number of stems.

Site name	Year	Number of plants sampled	Number of sampling squares	Mean number of plants per m^2	Total area of study site (m^2)	Estimated number of stems per site	Increase or decrease	Percent change
Red Fern lower	2011	74	27	2.7	4400	12059		
Red Fern lower	2012	43	27	1.6	4400	7007	-	42
Highway 43 upper	2011	17	21	0.8	2500	2024		
Highway 43 upper	2012	9	21	0.4	2500	1071	-	47
Highway 43 lower	2011	53	18	2.9	1800	5300		
Highway 43 lower	2012	39	18	2.2	1800	3900	-	26
Kyles upper	2011	15	9	1.7	100	167		
Kyles upper	2012	5	9	0.6	100	56	-	66
Red Fern upper	2012	8	21	0.4	2500	952		
Centerpoint lower	2012	15	21	0.7	2500	1786		
Centerpoint upper	2012	18	21	0.9	2500	2143		
Kyles lower	2012	45	21	2.1	2500	5357		

2011 study sites and total stem counts from the same sites in 2012 also was not found to be significant ($P > 0.05$).

E. PLANT CHARACTERS

Minimum, maximum, mean, and standard deviations for plant heights at *D. newtonianum* study sites can be found in Table 10. Plant heights ranged from a minimum height of 10 cm at Point Peter south in 2011 to a maximum height of 105 cm at Point Peter unburned in 2012. Reproductive structure averages for *D. newtonianum* study sites can be found in Table 11.

Minimum, maximum, mean, and standard deviations for plant heights at *T. ozarkana* study sites at can be found in Table 12. *Tradescantia ozarkana* plant heights ranged from a minimum height of 4 cm at Highway 43 lower in 2011 to a maximum height of 71 cm at Red Fern lower in 2011. Average plant heights for each site ranged from 19.8 cm at Kyles upper in 2012 to 43.6 cm at Red Fern lower in 2011. Reproductive structure averages for *T. ozarkana* study sites can be found in Table 13. The average number of seeds per fruit at each study site in 2012 can be found in Table 14. and the average number of stems per plant group in 2012 can be found in Table 15.

F. DISTANCE AND DIVERSITY

Site Euclidean distances for Moore's delphinium study sites was smallest for Point Peter unburned and Point Peter south (Euclidean distance = 0.364) (Table 16.). Gene Rush had the largest overall distance compared to other sites. The smallest Euclidean distance between Ozark spiderwort sites was the distance for Highway 43 upper and Highway 43 lower (Euclidean distance = 0.361) (Table 17.). Centerpoint upper had the farthest overall distance from other sites, so much so that distances between it and any other site were not below 0.600. Woody trees and shrubs identified from each study site can be found in Appendix C. for *D. newtonianum* and

Table 10. *Delphinium newtonianum* minimum, maximum, and mean plant heights and standard deviations for each study site. Note: *Point Peter north study site in 2012 had 1 plant, but was not included due to missing structures; the number of plants sampled at each site can be found in Table 8.

Site name	**Year**	**Minimum height (cm)**	**Maximum height (cm)**	**Mean plant height (cm) ± standard deviation**
Point Peter north	2011	34	61	46.7 ± 10.2
Point Peter north*	2012	-	-	-
Point Peter south	2011	10	70	50.4 ± 20.2
Point Peter south	2012	-	-	-
Point Peter unburned	2011	16	104	63.2 ± 17.2
Point Peter unburned	2012	40	105	52.5 ± 17.7
Buck Ridge	2011	17	64	38.2 ± 14.2
Buck Ridge	2012	65	65	65.0 ± 0.0
Calf Creek	2011	32	76	45.5 ± 11.8
Calf Creek	2012	28	28	27.6 ± 0.0
Gene Rush	2012	76	76	76.0 ± 0.0
Woolum	2012	31	51	40.1 ± 9.7
Dave Manes Bluff	2012	-	-	-

Table 11. Mean values for reproductive structures of *Delphinium newtonianum* plants at each study site. Note: SD = standard deviation; *Point Peter north study site in 2012 had only a single plant but was not included due to missing structures.

Site name	**Year**	**Number of plants sampled**	**Buds & flowers per plant ± SD**	**Fruits per plant ± SD**
Point Peter north	2011	7	3.0 ± 3.2	2.9 ± 2.7
Point Peter north*	2012	1	-	-
Point Peter south	2011	7	3.7 ± 3.8	4.1 ± 5.7
Point Peter south	2012	0	-	-
Point Peter unburned	2011	16	0.6 ± 1.1	8.2 ± 7.5
Point Peter unburned	2012	2	0.0 ± 0.0	3.0 ± 4.2
Buck Ridge	2011	11	2.4 ± 4.2	2.6 ± 2.5
Buck Ridge	2012	1	0.0 ± 0.0	0.0 ± 0.0
Calf Creek	2011	12	2.8 ± 2.8	0.9 ± 2.0
Calf Creek	2012	1	0.0 ± 0.0	5.0 ± 0.0
Gene Rush	2012	1	0.0 ± 0.0	0.0 ± 0.0
Woolum	2012	5	0.0 ± 0.0	5.2 ± 8.9
Dave Manes Bluff	2012	0	-	-

Table 12. *Tradescantia ozarkana* minimum, maximum, and mean plant heights and standard deviations for each study site. The number of plants sampled at each site can be found in Table 9.

Site name	**Year**	**Minimum height (cm)**	**Maximum height (cm)**	**Mean plant height (cm) ± standard deviation**
Red Fern lower	2011	15	71	43.6 ± 10.1
Red Fern lower	2012	6	68	28.8 ± 15.4
Highway 43 upper	2011	20	53	39.9 ± 8.7
Highway 43 upper	2012	20	36	27.4 ± 8.7
Highway 43 lower	2011	4	65	37.2 ± 13.1
Highway 43 lower	2012	15	56	32.1 ± 10.8
Kyles upper	2011	32	53	39.2 ± 6.0
Kyles upper	2012	7	34	19.8 ± 11.4
Red Fern upper	2012	16	31	25.9 ± 4.9
Centerpoint lower	2012	8	55	38.8 ± 15.3
Centerpoint upper	2012	22	56	41.2 ± 10.7
Kyles lower	2012	52	19	36.9 ± 8.8

Table 13. Mean values for reproductive structures of *Tradescantia ozarkana* plants at each study site. Note: SD = standard deviation; the distinction between immature and mature fruits was not made for study sites sampled in 2011; *Red Fern upper reproductive structures had disintegrated and thus could not be counted.

Site name	**Year**	**Number of plants sampled**	**Buds per plant ± SD**	**Flowers per plant ± SD**	**Immature fruits per plant ± SD**	**Mature fruits per plant ± SD**	**Combined immature & mature fruits per plant ± SD**
Centerpoint lower	2012	15	8.6 ± 7.6	1.7 ± 1.1	7.7 ± 6.3	0.7 ± 0.8	8.3 ± 6.9
Centerpoint upper	2012	18	4.1 ± 2.8	0.6 ± 0.8	7.2 ± 4.2	3.3 ± 3.4	10.5 ± 6.6
Red Fern lower	2012	43	8.1 ± 3.7	1.1 ± 1.6	0.4 ± 0.9	0.0 ± 0.0	0.4 ± 0.9
Red Fern upper*	2012	8	-	-	-	-	-
Kyles lower	2012	45	1.0 ± 2.1	0.8 ± 1.0	3.1 ± 2.4	4.0 ± 4.0	7.1 ± 5.3
Kyles upper	2012	5	6.0 ± 1.9	1.6 ± 1.1	3.6 ± 5.9	0.0 ± 0.0	3.6 ± 5.9
Highway 43 lower	2012	39	7.4 ± 4.6	1.2 ± 1.4	4.8 ± 5.9	0.9 ± 2.7	5.7 ± 8.4
Highway 43 upper	2012	9	7.9 ± 2.4	0.8 ± 0.3	7.7 ± 1.1	0.8 ± 1.3	8.4 ± 8.3
Red Fern lower	2011	74	1.2 ± 2.4	0.4 ± 0.8	-	-	9.7 ± 6.9
Highway 43 upper	2011	17	0.5 ± 1.7	0.2 ± 0.7	-	-	11.6 ± 12.7
Highway 43 lower	2011	53	4.9 ± 6.6	0.7 ± 0.9	-	-	5.6 ± 8.8
Kyles upper	2011	15	0.0 ± 0.3	0.5 ± 1.0	-	-	9.5 ± 5.6

Table 14. Average number of seeds per fruit for *Tradescantia ozarkana* study sites in 2012.

Site name	Number of fruits	Number of seeds	Average number of seeds per fruit
Centerpoint lower	68	262	3.9
Centerpoint upper	55	197	3.6
Red Fern lower	63	222	3.5
Red Fern upper	52	153	3.0
Kyles lower	96	191	2.0
Kyles upper	100	345	3.5
Highway 43 lower	55	296	5.4
Highway 43 upper	43	132	3.1

Table 15. Average number of stems per plant group for *Tradescantia ozarkana* study sites in 2012.

Year	Site name	Average number of plants per group
2012	Centerpoint lower	4.5
2012	Centerpoint upper	2.2
2012	Red Fern lower	6.6
2012	Red Fern upper	3.0
2012	Kyles lower	4.1
2012	Kyles upper	1.3
2012	Highway 43 lower	2.4
2012	Highway 43 upper	1.3

(Table 16.) Euclidean distance values for pairwise comparisons among *Delphinium newtonianum* study sites using species presence/absence data. Taxa not identified to species level were not included in the analysis except for genera unique to a particular study site.

	Gene Rush	**Woolum**	**Dave Manes Bluff**	**Point Peter north**	**Point Peter south**	**Point Peter unburned**	**Buck Ridge**	**Calf Creek**
Gene Rush	****							
Woolum	0.604	****						
Dave Manes Bluff	0.624	0.547	****					
Point Peter north	0.706	0.736	0.533	****				
Point Peter south	0.647	0.685	0.565	0.394	****			
Point Peter unburned	0.689	0.739	0.630	0.441	0.364	****		
Buck Ridge	0.617	0.541	0.536	0.582	0.543	0.514	****	
Calf Creek	0.593	0.625	0.484	0.487	0.477	0.509	0.481	****

(Table 17.) Euclidean distance values for pairwise comparisons among *Tradescantia ozarkana* study sites using species presence/absence data. Taxa not identified to species level were not included in the analysis except for genera unique to a particular study site.

	Kyles lower	**Kyles upper**	**Centerpoint upper**	**Centerpoint lower**	**Red Fern lower**	**Red Fern upper**	**Highway 43 upper**	**Highway 43 lower**
Kyles lower	****							
Kyles upper	0.490	****						
Centerpoint upper	0.685	0.689	****					
Centerpoint lower	0.431	0.619	0.600	****				
Red Fern lower	0.476	0.586	0.810	0.546	****			
Red Fern upper	0.456	0.576	0.705	0.491	0.504	****		
Highway 43 upper	0.517	0.571	0.667	0.480	0.552	0.495	****	
Highway 43 lower	0.525	0.538	0.702	0.504	0.500	0.486	0.361	****

Appendix D. for *T. ozarkana*. Herbaceous, graminoid, and seedless vascular plant lists can be found in Appendices E. - L. for *D. newtonianum* and Appendices M. - T. for *T. ozarkana*.

G. PCA and FACTOR ANALYSES

A PCA of soil parameters (Figure 18.) for *D. newtonianum* resulted in the retention of five principal components which explained 95.9% of the variance in the data. Of these, PC 1 – PC 4 had eigenvector values ≥ 1.00 (Appendix U.); PC 5 was also included for further analysis because it accounted for 4.1% of the variance in the data. ANOVAs to test for significant linear correlations between each PC and study site stem densities were not found to be significant for any component (Appendix V.). Loading scores and correlation coefficients can be found in Appendix W. and Appendix X., respectively.

A PCA for physical parameters (Figure 19.) resulted in the retention of five components which explained 95.1% of the variance in the data. PC 1 - PC 4 had eigenvector values ≥ 1.00; PC 5 eigenvector value was <1.0 but was included because it accounted for 6.1% variance in the data (Appendix Y.). ANOVAs to test for significant correlations between each PC and study site stem densities were not found to be significant (Appendix V.). Loading scores and correlation coefficients can be found in Appendix Z. and Appendix AA., respectively.

Five factors were retained and rotated using oblimin rotation in factor analyses for both physical and soil variables for *D. newtonianum* data. ANOVAs to test for significant correlations between each factor and study site stem densities were not significant for either soil or physical factors; however, a trend was shown with physical variables and factor 2 ($P = 0.0766$)(Appendix V.). Factor 2 loaded high with woody species richness (1.0397), and with negative percent rock cover (-0.8065) (Appendix AB.) Factor loadings for soil variables can be found in Appendix AC.

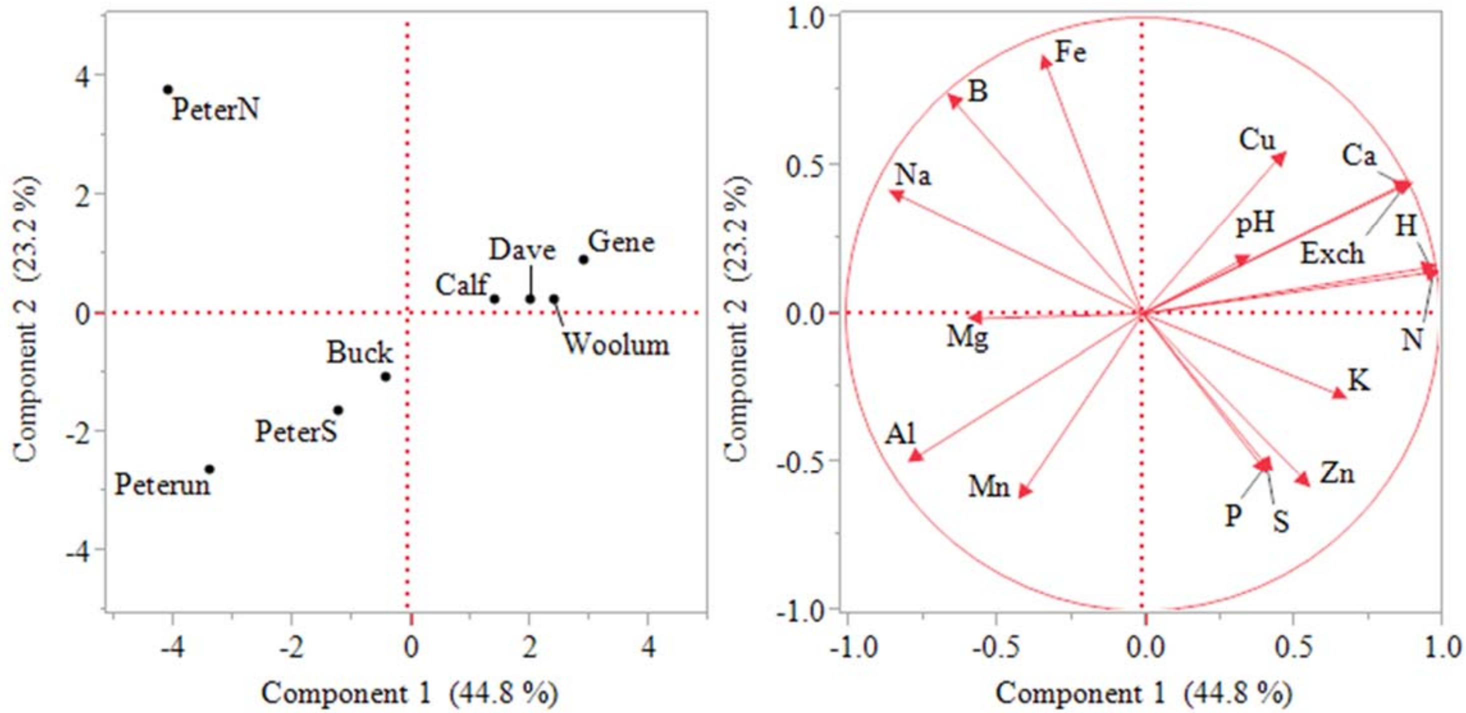

Figure 18. Score plot (left) and loading plot (right) of the first two axes derived from a Principal Component Analysis (PCA) using soil variables collected from *Delphinium newtonianum* study sites. Note: PeterN = Point Peter north; Peterun = Point Peter unburned; PeterS = Point Peter south; Buck = Buck Ridge; Calf = Calf Creek; Dave = Dave Manes Bluff; Gene = Gene Rush; Al = aluminum; B = boron; Ca = calcium; Exch = total exchange capacity; Fe = iron; H = humus; K = potassium; Mg = magnesium; Mn = manganese; N = nitrogen; Na = sodium; P = phosphorus; S = sulfur; and Zn = zinc.

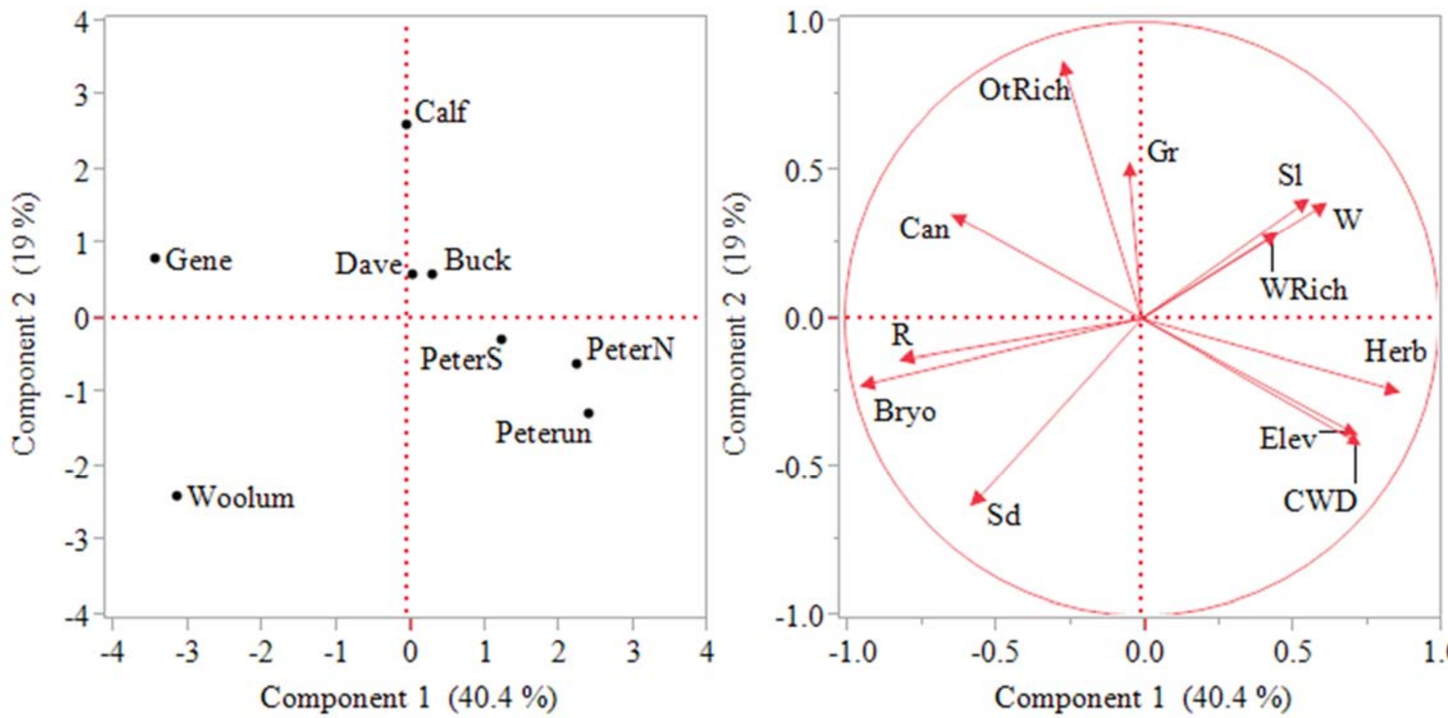

Figure 19. Score plot (left) and loading plot (right) of the first two axes derived from a Principal Component Analysis (PCA) using physical variables from *Delphinium newtonianum* study sites. Note: PeterN = Point Peter north; Peterun = Point Peter unburned; PeterS = Point Peter south; Buck = Buck Ridge; Calf = Calf Creek; Dave = Dave Manes Bluff; Gene = Gene Rush; Herb = % herbaceous cover; Elev = elevation; CWD = % coarse woody debris; Gr = % graminoid cover; W = % woody plant cover; Sl = % slope; R = % rock cover; Can = % canopy cover; Bryo = % bryophyte cover; WRich = woody species richness; Otrich = plant species richness other than woody plants; Sd = % seedless vascular plant cover.

.　　A PCA using soil parameters (Figure 20.) attained from *T. ozarkana* sites resulted in retaining five PC's (eigenvectors ≥1.00) which explained 94.2% of the variance in the data (Appendix AD.). ANOVAs to test for significant correlations between each principal component and study site stem density were significant (P = 0.0136) for PC 2 and stem density (Figure 21.)(Appendix V.) The soil variables contributing the most to PC 2 were magnesium (0.8403), copper (0.8905), zinc (0.8737), and phosphorus (-0.6089) (Appendix AE.). Correlation coefficients can be found in Appendix AF.

The PCA conducted using *Tradescantia ozarkana* physical variables (Figure 22.) resulted in keeping five principal components that explained 96.8% of the data variance. PC 1 - PC 4 had eigenvalues >1.0 (Appendix AG.). Although PC 5 eigenvalue was <1.0, it was retained because it explained 4.9% variance. ANOVAs to test for significant correlations between each principal component and study site stem density were not significant for any component (Appendix V.). Loading scores for physical variables and correlation coefficients can be found in Appendix AH. and Appendix AI., respectively.

Five factors were retained and rotated using oblimin rotation in factor analyses for both physical and soil variables for *T. ozarkana* data. ANOVAs were run to test for significant correlations between each factor and study site stem density. A significant result (P = 0.0095) was found for soil factor 3 and stem density (Figure 23.) (Appendix V.). The highest loadings for soil factor 3 included copper (0.944), magnesium (0.9252), zinc (0.6963), and iron (0.5654) (Appendix AJ.) No other significant results were identified from *T. ozarkana* factor analyses. Factor loadings for physical variables can be found in Appendix AK.

H. HABITAT MODELING

Using *T. ozarkana* study site areas to predict habitat, sites were found to have aspects

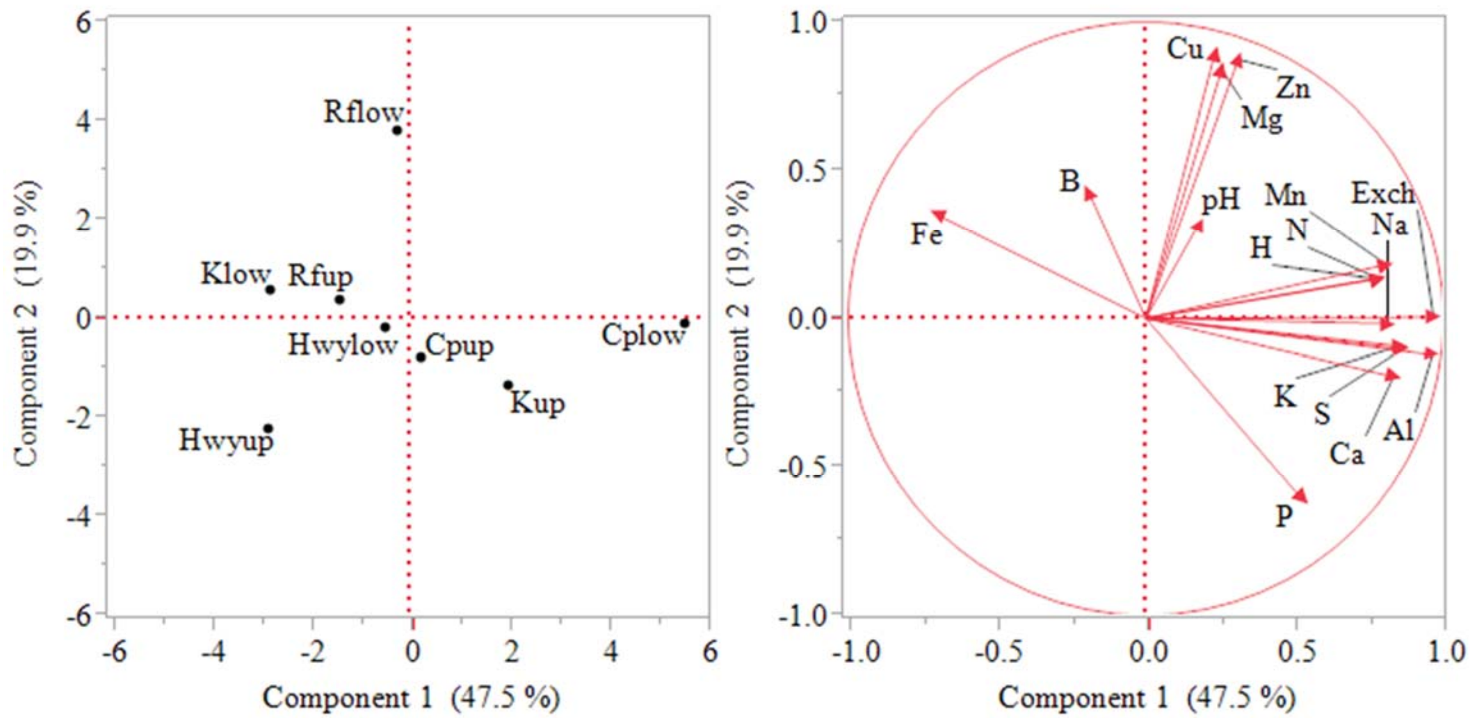

Figure 20. Score plot (left) and loading plot (right) of the first two axes derived from a Principal Component Analysis (PCA) using soil variables collected from *Tradescantia ozarkana* study sites. Note: Klow = Kyles lower; Kup = Kyles upper; Rfup = Red Fern upper; Rflow = Red Fern lower; Cpup = Centerpoint upper; Cplow = Centerpoint lower; Hwyup = Highway 43 upper; Hwylow = Highway 43 lower; Al = aluminum; B = boron; Ca = calcium; Exch = total exchange capacity; Fe = iron; H = humus; K = potassium; Mg = magnesium; Mn = manganese; N = nitrogen; Na = sodium; P = phosphorus; S = sulfur; and Zn = zinc.

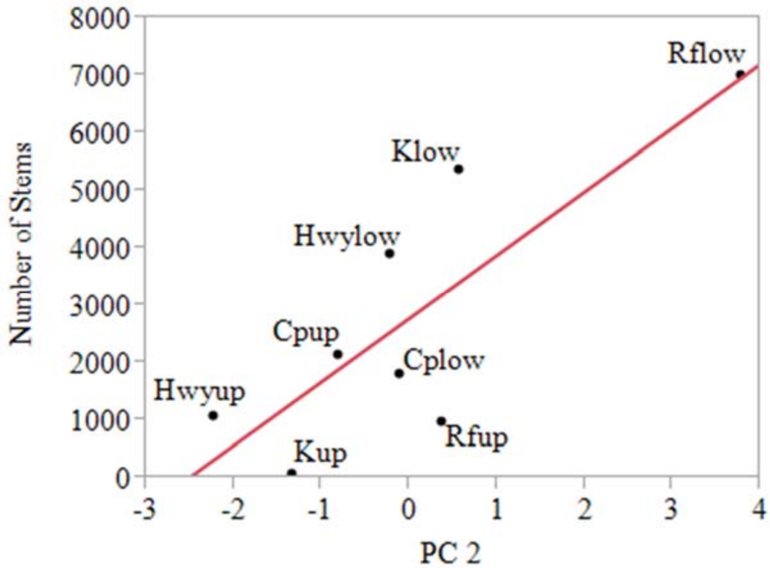

Figure 21. Graph of the significantly positive correlation (P = 0.0136) between the estimated number of stems per site and PC 2 from *Tradescantia ozarkana* soil PCA. The best fit line is shown. The soil variables loading highest on PC 2 were copper, zinc, and magnesium, all with loading scores > 0.8000. See Appendix AE. for the complete list of loading scores.

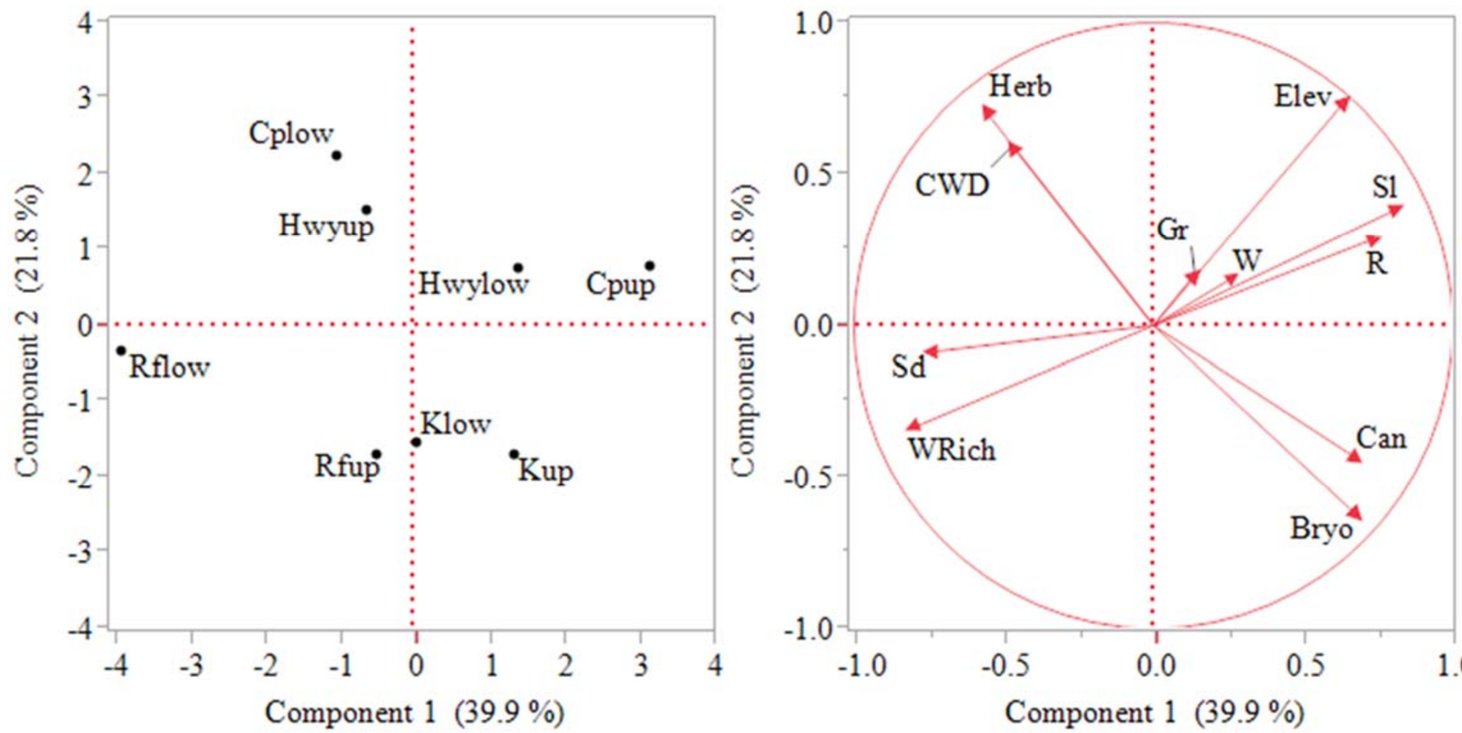

Figure 22. Score plot (left) and loading plot (right) of the first two axes derived from a Principal Component Analysis (PCA) using physical variables collected from *Tradescantia ozarkana* study sites. Note: Klow = Kyles lower; Kup = Kyles upper; Rfup = Red Fern upper; Rflow = Red Fern lower; Cpup = Centerpoint upper; Cplow = Centerpoint lower; Hwyup = Highway 43 upper; Hwylow = Highway 43 lower; Herb = % herbaceous cover; Elev = elevation; CWD = % coarse woody debris; Gr = % graminoid cover; W = % woody plant cover; Sl = % slope; R = % rock cover; Can = % canopy cover; Bryo = % bryophyte cover; WRich = woody species richness; Sd = % seedless vascular plant cover.

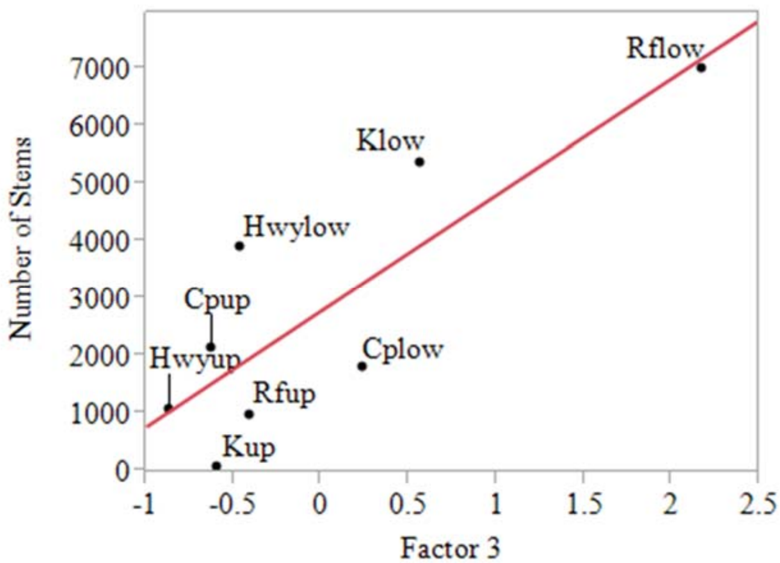

Figure 23. Graph of the significantly positive correlation (P = 0.0095) between the estimated number of stems per site and Factor 3 from *Tradescantia ozarkana* soil factor analysis. The best fit line is shown. The soil variables loading highest on Factor 3 were copper (0.944), magnesium (0.9252), zinc (0.6963), and iron (0.5654). See Appendix AJ. for the complete list of loading scores. Note: Klow = Kyles lower; Kup = Kyles upper; Rfup = Red Fern upper; Rflow = Red Fern lower; Cpup = Centerpoint upper; Cplow = Centerpoint lower; Hwyup = Highway 43 upper; Hwylow = Highway 43 lower.

facing in all directions according to GIS. However, 4 out of the 10 classes contained 76% of the pixels. Those classes corresponded to 0° - 90°, or north to east, and 157.5° - 202.5°, or south. All slope classes were present for the areas studied. The two most frequently occurring slope percentages were between 35% - 40% and 40% - 45% slope. The soils layer indicated that the study sites were on the Nella-Steprock, Noark, Razort soils, and Enders-Nella complexes. The geology layer indicated the study sites were on sandstone-shale, sandstone-siltstone, and limestone-chert geologic features. The initial habitat model using the study site areas to output a raster using the Boolean operator "&" showed that out of the 12 test sites, only 4 were correctly classified (Figure 24.)

The second model for *T. ozarkana* utilizing the ranked slope, aspect, and elevation data from the 8 study sites output a projected model with every cell of the raster of the area of interest to have a value of at least 2 due to the presence of all classes of aspects and slopes found at the 8 study sites. The 12 points used for validation of the model indicated that 7 of the 12 locations, or 58% of the cells, had a value ≥5, or the upper ½ of the possible values (Figure 25.).

The third model for *T. ozarkana* utilizing the ranked slope, aspect, and elevation data of the 20 locations classified 6 of the 22 points, or 27%, to values ≥6 (Figure 26.) When the 22 points were placed in the aspect/slope raster, 10 points had values ≥ 4, the upper ½ of the potential values; the aspect/elevation raster contained a point with a value = 0, and only 6 of the remaining points had values ≥4; elevation/slope raster also included a point with a value = 0 and only 5 of the remaining points had values ≥4.

When *D. newtonianum* study site areas were placed in GIS, the sites were found to include most of the aspect classes. However, 4 of the classes represented 91% of the pixels classified. Those aspects correspond to 227.5° - 360°, or west to north, and 112.5° - 157.5°, or

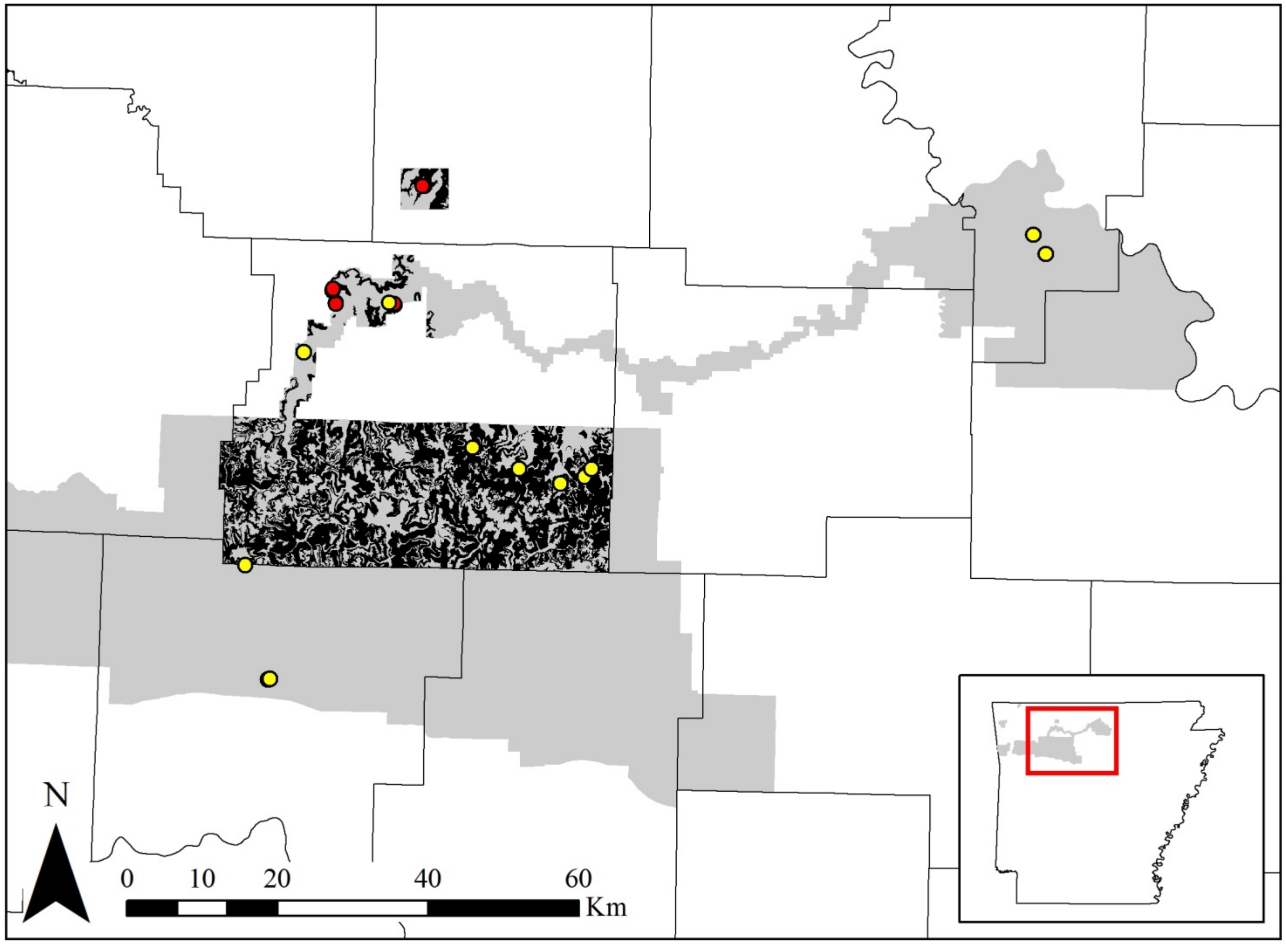

Figure 24. Map of projected potential habitat for *T. ozarkana* using slope, aspect, elevation, soil, and geology raster layers with the Boolean operator "&". Note: black areas represent potential habitat; medium grey is the area of interest upon labeled Arkansas counties; inset is of the state of Arkansas with the extent of the larger map outlined in red; the study sites are in red and the test sites are in yellow.

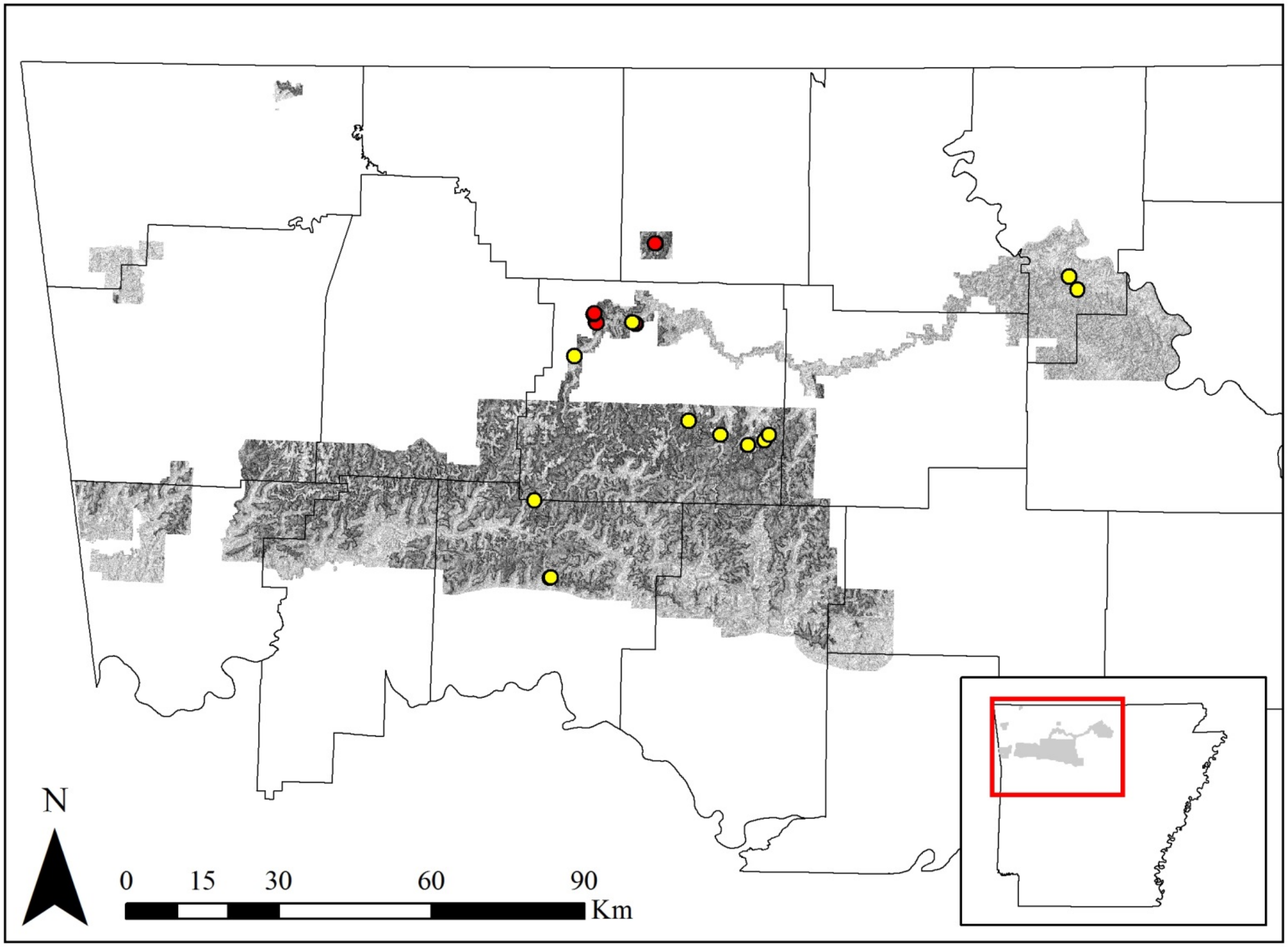

Figure 25. Map of projected potential habitat for *T. ozarkana* using slope, aspect, and elevation rasters ranked using the original 8 study site areas upon labeled Arkansas counties. Note: potential habitat ranges from the darkest areas (most suitable) to the lightest areas (least suitable); the study sites are in red and the test sites are in yellow; inset is of the state of Arkansas with the extent of the larger map outlined in red.

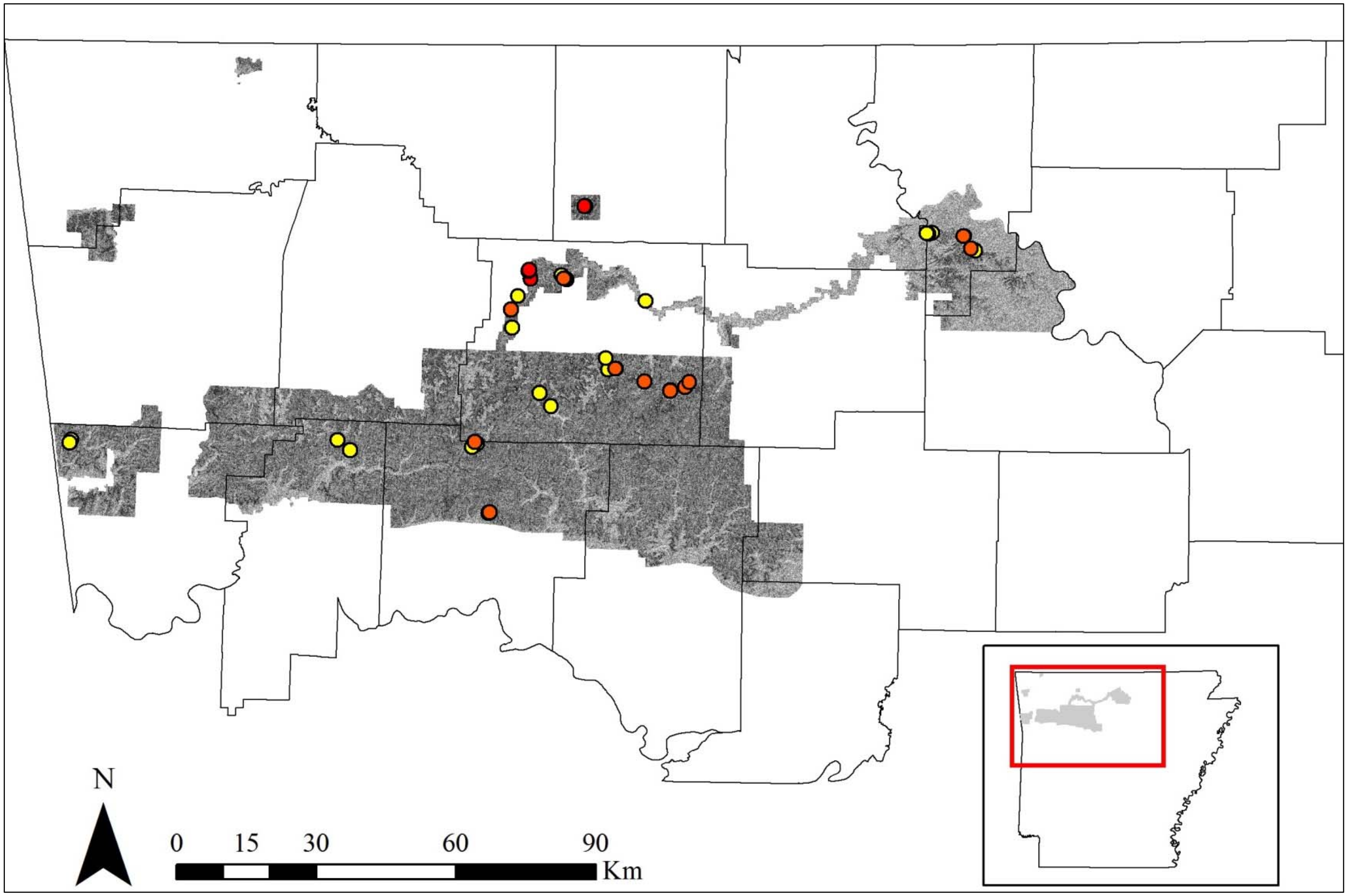

Figure 26. Map of projected potential habitat for *T. ozarkana* using slope, aspect, and elevation rasters ranked using 20 point locations upon labeled Arkansas counties. Note: potential habitat ranges from the darkest areas (most suitable) to the lightest areas (least suitable); the original study sites are in red; the sites used in model 1 and for further model refining are in orange; the test points are in yellow; inset is of the state of Arkansas with the extent of the larger map outlined in red.

southeast. All slope classes were present for the areas studied, but generally the slopes were not flat and the top two pixels classes represented slopes from 15% - 20% and 35% - 40% slopes. The soils layer indicated that the study sites were on Nella-Steprock-Mountainburg, Nella, Arkana-Moko, Clarksville, Moko-Rock, Healing, and Noark soil complexes. The geology layer indicated that the study sites were located on limestone-chert, sandstone-siltstone, and limestone-siltstone geologic features. None of the 12 sites were correctly classified using this model (Figure 27.).

The second model using data from the study site areas and the 12 point locations to increase the data in the model output a potential habitat area which correctly classified 19 of the 48 locations, or approximately 40% of the points (Figure 28.).

The third model created utilizing the ranked slope, aspect, and elevation rasters correctly classified all 48 points that were not previously used in the model (Figure 29). The majority of the points were expected to have raster values ranging from 5 - 9, which would represent the upper 50% of the values; however, raster values for the 48 points centered around a raster value = 5. When the 48 points were placed in both the aspect/slope raster and the aspect/elevation raster, all points were classified and again the values for the points were approximately centered around a raster value of 3 with potential values ranging from 0 - 6. When the points were placed in to the elevation/slope raster, 8 of the 48 points were not correctly classified and had a raster value = 0.

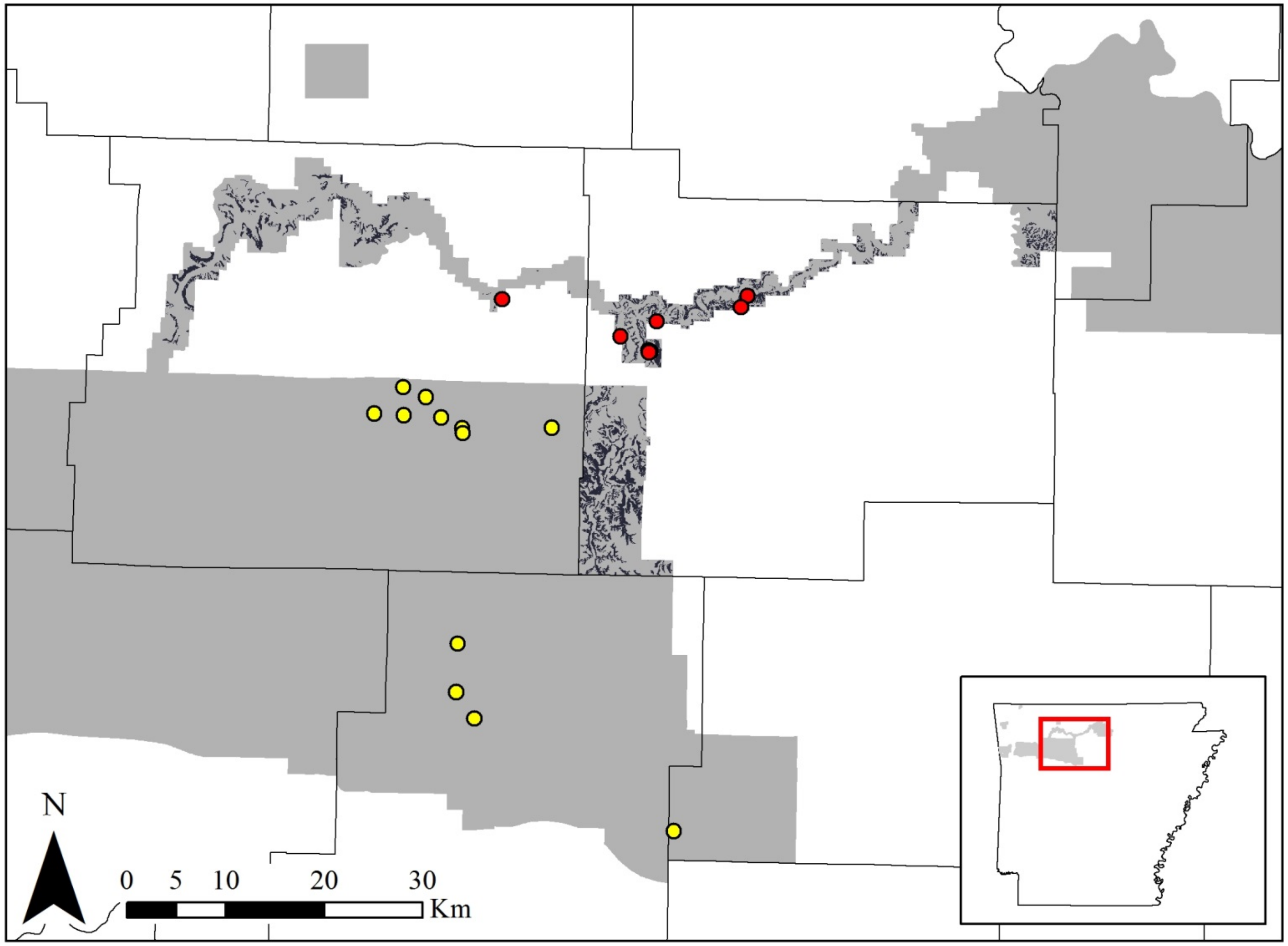

Figure 27. Map of projected potential habitat for *D. newtonianum* using slope, aspect, elevation, soil, and geology raster layers with the Boolean operator "&". Note: black areas represent potential habitat; medium grey is the area of interest upon labeled Arkansas counties; inset is of the state of Arkansas with the extent of the larger map outlined in red; the study sites are in red and the test sites are in yellow.

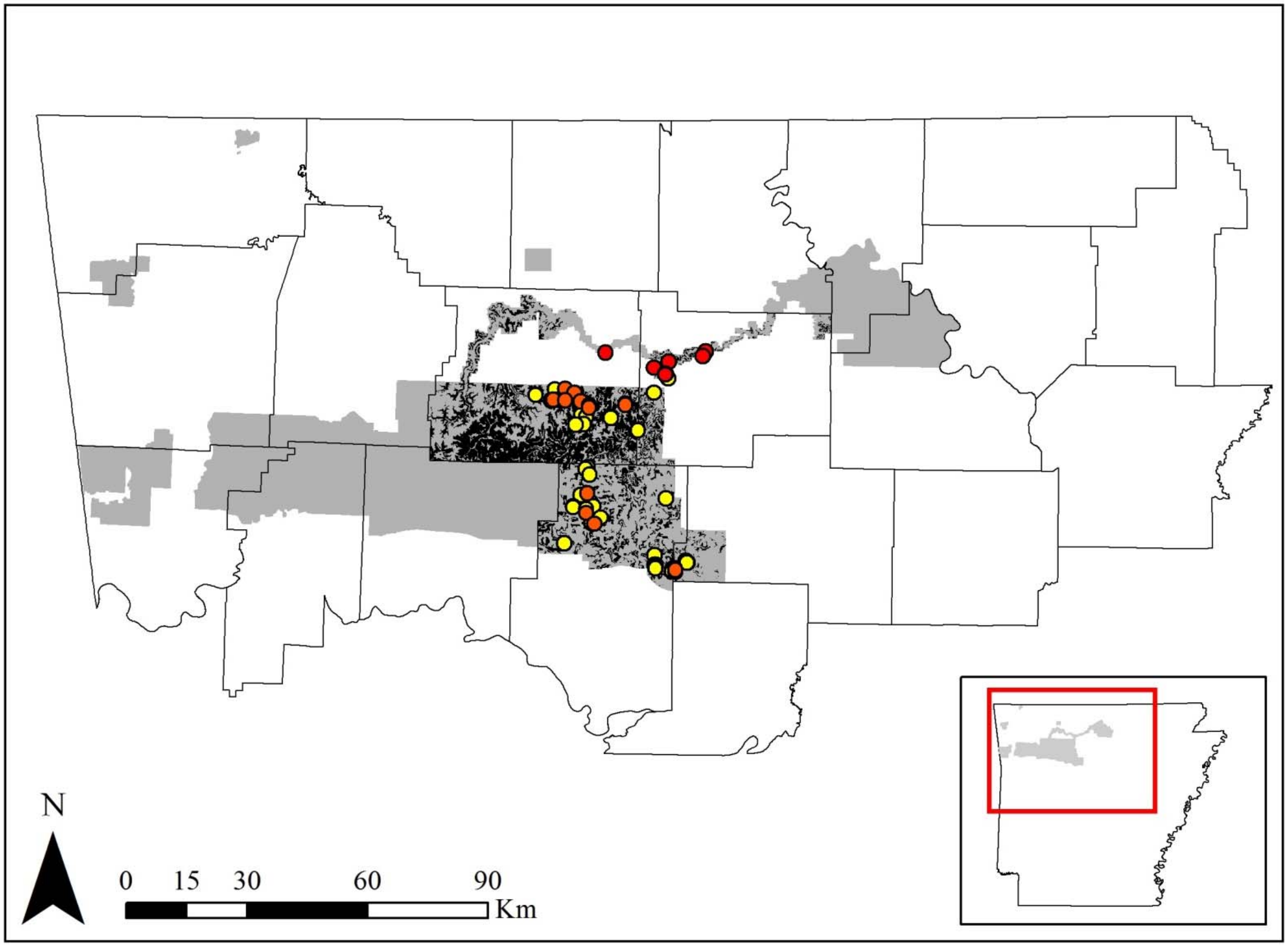

Figure 28. Map of projected potential habitat for *D. newtonianum* using slope, aspect, elevation, soil, and geology raster layers with the Boolean operator “&”. Note: black areas represent potential habitat; medium grey is the area of interest upon labeled Arkansas counties; inset is of the state of Arkansas with the extent of the larger map outlined in red; the study sites are in red, the sites used in model 1 and for further model refining are in orange; the test points are in yellow.

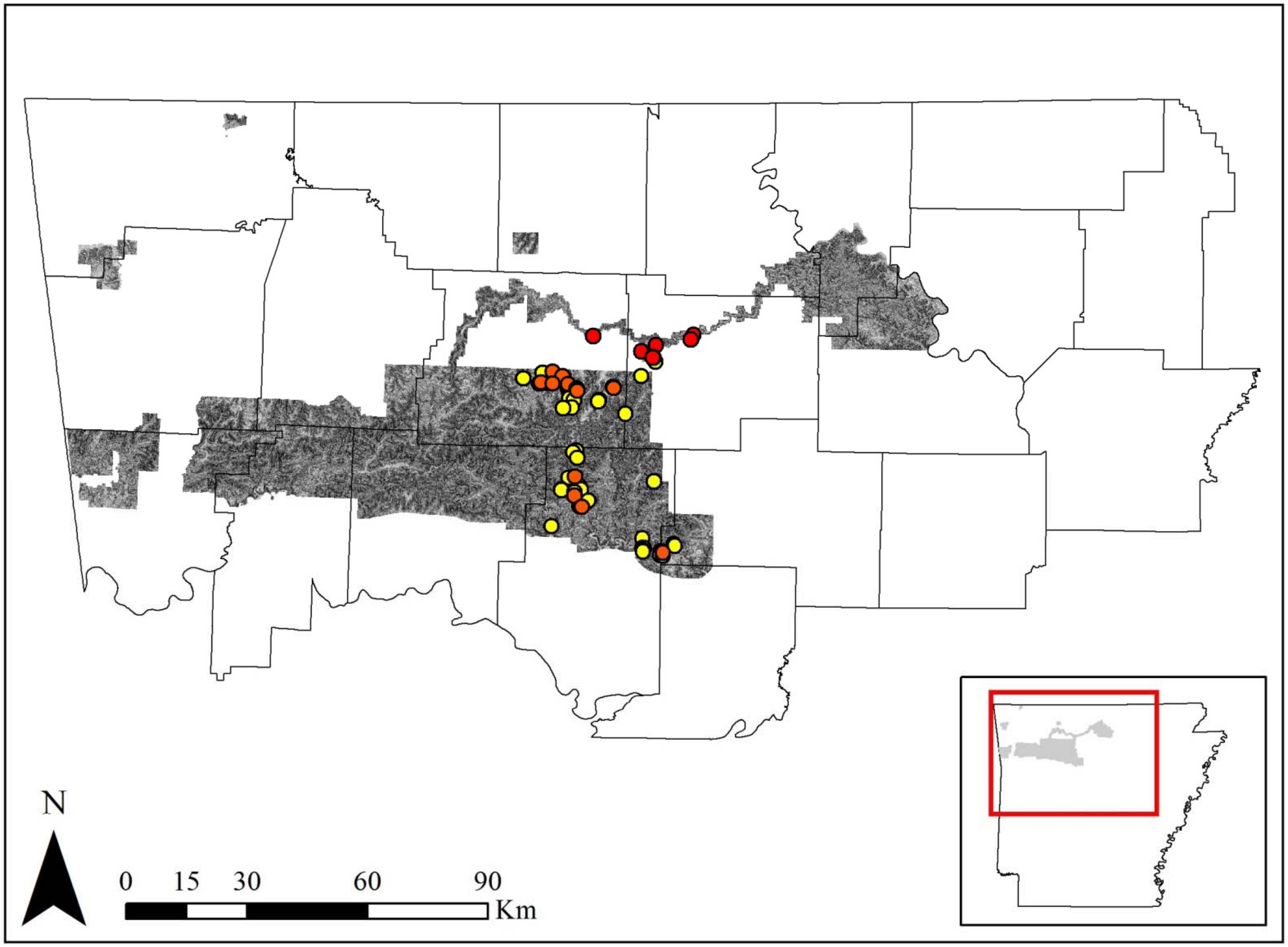

Figure 29. Map of projected potential habitat for *D. newtonianum* using slope, aspect, and elevation rasters ranked using 20 point locations upon labeled Arkansas counties. Note: potential habitat ranges from the darkest areas (most suitable) to the lightest areas (least suitable); the original study sites are in red; the sites used in model 1 and for further model refining are in orange; the test points are in yellow; inset is of the state of Arkansas with the extent of the larger map outlined in red.

IV. DISCUSSION

Tradescantia ozarkana combined location data from data collected at each site and data extracted from GIS indicate elevation preference for the species are at the middle to higher elevations in the Interior Highlands, at approximately 326 meters to 643 meters. Although the species was found at a variety of aspects, it is least likely to be found between southern and western facing aspects were the sun hits the slopes for the longest amount of time. The species can be found on all slopes from flat, flood prone areas such as witnessed at Red Fern lower site after heavy rains in the spring of 2011, to steep rocky bluffs where site surveys were not possible due to the dangerous site conditions.

Comparisons of average percent coverage of lower forest strata, rocky ground cover, and coarse woody debris between sites with the highest and lowest densities of stems per m^2 for the year percent coverage sampling was conducted did not show any obvious trends. *Tradescantia ozarkana* does not appear to be negatively affected by high percentages of ground cover as seen with Red Fern lower in 2011 and Highway 43 lower in 2011, the two study sites with the highest average stem density per m^2 and the highest overall percentage of woody plant, graminoid, and herbaceous plant cover combined.

Percent canopy cover for all study sites, other than Centerpoint upper for which data was unavailable, was reasonably high with Red Fern upper having the highest percentage of canopy cover at almost 95%. Because only one digital photograph was taken from the center of each study site to estimate percent canopy cover, caution should be used to estimate light requirements for this species. *Tradescantia ozarkana* was seen growing in dense clusters in the area immediately surrounding recently fallen trees at multiple study sites and on nearly open bluff edges. GIS layers of percent canopy coverage exist for some areas; however, the data are not at a high enough resolution to be used for small site areas as used in this study. LIDAR, or light detection and ranging, a type of remote sensing that uses laser pulses from an aerial platform, will be an invaluable tool to accurately measure canopy cover once the data become available for public use (Lefsky *et al.* 2003).

Plants found at Red Fern lower had the tallest individual plant for both 2011 and 2012; however, only Red Fern in 2011 had the highest average plant height. This can be attributed to a loss of the upper soil layers caused from a flooding event that occurred at this site in 2011.

All taxa in the genus *Tradescantia* have determinate inflorescences, but flower buds were difficult to count due to their location in the axils of the leaves (Zomlefer 1994). Flowering plants were seen as early as 6 April to as late as 25 May from the sites used in this study, and flowering plants were seen at locations near the study sites several days before and after these dates. The blooming period is long for this species, potentially as long as two months, so data collected on reproductive structures is potentially highly variable depending on the date in which the data were collected.

Plant aggregations are most likely due to limited dispersion capabilities. Factors unique to each plant's location, including water runoff and steepness of the slopes on which the plants occur can affect the distance seeds are able to disperse from the parental plant. *Tradescantia ozarkana*, along with other members in the genus which are planted for ornamental purposes, are capable of asexual propagation by rooting at the nodes (eFlora 2008). This also likely contributes to the dense aggregations of stems.

Literature on soil preference for *T. ozarkana* states the species is found on calcareous substrates, which are alkaline and have pH values above 7.0 (Yatskievych and Steyermark 1999). pH values from the sites used in this study disagree and indicate the species can occur on slightly acidic soils, at least as low as 6.1. Although soil depth at each study was not able to be quantified, it was noted that *T. ozarkana* is capable of thriving on, and at times densely populating, extremely thin soils resting on the upper surfaces of large rocks.

Both the soil factor analysis and soil PCA gave significant positive correlations between high values of magnesium, copper, and zinc and high stem density. Magnesium, a macronutrient, is a component of chlorophyll and an enzyme activator (Gurevitch *et al.* 2006). Both copper, which is important for pollen formation and ovule fertilization, and zinc, important for enzymes and hormone metabolism, are micronutrients, but are still necessary for proper growth, although required in smaller amounts than macronutrients. Examination of the correlation coefficient matrix for the soil parameters shows magnesium, copper, and zinc are all highly correlated with one another (correlation coefficients ≥ 0.7494). Because of the high correlations, it is unknown whether all three nutrients, combinations of two nutrients, or a single nutrient of the three is causing positive correlations between high stem density and both factor 3 and PC 2. PC 2 also loaded phosphorus, a macronutrient, highly negatively on the component. Perhaps *T. ozarkana* has an increased competitive advantage over other plant species in areas with reduced soil phosphorus levels.

Euclidean distance values using plant species presence/absence data were relatively small for pairs of sites that were in the same general area, except for the distance between Centerpoint upper and Centerpoint lower. Overall, Centerpoint upper had the largest distances among the other sites. Although percent canopy cover data for Centerpoint upper is not available, the site visually had the least canopy cover compared to the other seven sites. This probably contributed to the difference in plant species found at that location. Woody species in common to most of the sites included *Acer saccharum* (sugar maple), *Carya ovata* (shagbark hickory), *Celtis* *occidentalis* (common hackberry), *Cercis canadensis* (redbud), *Fraxinus americana* (white ash), *Fraxinus quadrangulata* (blue ash), *Juglans nigra* (black walnut), *Morus rubra* (red mulberry), *Quercus muehlenbergii* (chinquapin oak), *Quercus rubra* (Northern red oak), and *Ulmus rubra* (slippery elm). Herbaceous plants species common to most of the sites included *Arisaema triphyllum* (Jack-in-pulpit), *Galium aparine* (sticky-willy), *Maianthemum racemosum* (feathery-false-Solomon's-seal), *Menispermum canadense* (Canadian moonseed), *Parthenocissus quinquifolia* (Virginia-creeper), *Sanguinaria canadensis* (bloodroot), *Toxicodendron radicans* (Eastern poison ivy), and *Viola pubescens* (downy yellow violet).

Non-native and invasive plant species identified from *T. ozarkana* study sites were limited in in number. Centerpoint upper had the most non-native plants, with only three species. These were *Digitaria ischaemum* (smooth crab grass), *Perilla frutescens* (beefsteakplant), and *Taraxacum officinale* (common dandelion). These plants were found mostly on or next to the hiking trail that intersected the study area. The non-native species did not appear to pose a threat for future population growth for *T. ozarkana*.

Habitat modeling using GIS was only slightly successful. The initial model using the 8 study site areas to output a raster using the Boolean operator "&" only correctly classified 33% of the test sites (Figure 24.). The soils raster used in the model was too specific for a broad selection of soils throughout the area of interest. Each entry in the soil attribute table corresponded to a soil complex that also had an associated percent slope, meaning there were multiple entries in the attribute table for the same soil characteristics with different slope percentages. In order to use percent slope as a separate indicative factor for habitat selection, only the specific soil type and associated slope found from data extraction were used. Because all classes of the aspect and slope rasters were present at the study sites, the model created was not able to reduce the slope and aspect data for the area of interest. Further, the geology raster selection using the study sites did not limit the area of interest, other than a small portion in the lower Buffalo Wilderness.

The second model created for *T. ozarkana* using only the ranked slope, elevation, and aspect rasters and the data extracted from the area of the 8 study sites correctly classified 7 of the 12 test locations, or 58% of the cells, to a value ≥5 on a scale from 2 - 9 (Figure 25.). Two was the minimum value for a cell because every cell had a slope and aspect associated with it, and all classes of slope and aspect were ranked (1 - 3) prior to the addition of the 3 rasters in the raster calculator. The model created using this method included a projected potential habitat value for every cell rather than elimination of cells, but this method does not narrow the search area, only suggests areas that are best suitable versus least suitable.

The third model for *T. ozarkana* used fewer overall total cells to extract data from to create the model, but the cells used were wider spread across the area of interest and potentially better at representing the species' habitat preference. However, this was not the case when the test points were placed in the projected habit area, which only correctly classified 6 of the 22 points, or 27%, to values from 6 - 9 (Figure 26.). Examination of the raster values for the 22 test points when pairs of the ranked habitat rasters were added together showed that the aspect/slope raster best classified the points. The aspect/elevation and elevation/slope rasters did poorly to classify the test points, with 2 points that were not correctly classified. This suggests that out of the three variables, elevation is the least important.

Tradescantia ozarkana is one of several species of *Tradescantia* that exist as diploids or tetraploids (Anderson and Sax 1936, Yatskievych and Steyermark 1999). Characteristics stated as common to the tetraploid species of *Tradescantia* include longer blooming periods when compared to diploids and triploids. The blooming times for sites used in this study are nearly two months long, and is consistent with Anderson and Sax (1936). Other shared characteristics among tetraploids are vigor and wide distributions. Although comparisons were not made among *T. ozarkana* site stem densities and other *Tradescantia* species' site densities, the estimated number of stems for 6 out of 8 study sites exceeded 1,000 stems per site, with one of those sites, Red Fern lower, exceeding 12,000 stems. These estimated densities support a high vigor rate characteristic for tetraploid *T. ozarkana*. The limited distribution of this species is the only characteristic stated by Anderson and Sax that does not coincide with the other tetraploid *Tradescantia* species in North America (1936). Perhaps *T. ozarkana* is a relatively newly formed (neoendemic) species that has not yet reached the boundaries of its potential distribution.

Delphinium newtonianum location data collected *in situ* and extracted from GIS indicate elevation preference for this species in the Interior Highlands is at middle elevations from approximately 194 - 608 meters. The aspect values taken from the center of each visited site were in a very narrow range with a definitive west, southwest direction, although not all the area of every site was of the same aspect. Gene Rush, Woolum, and Dave Manes Bluff in particular had areas with slight inclines with aspects deviating from west and northwest where *D. newtonianum* was found. Percent slope is not much of a factor for *D. newtonianum*, although few locations had slopes ≥61%. As percent slope increases, the effect from aspect becomes greater. Because of this, the importance of aspect for *D. newtonianum* is also probably greater as percent slope increases.

Stem density estimates for each site are inaccurate and should not be used in population estimates. The sampling method design did not correspond to the species spatial distribution at many of the sites, some of which only contained the species in a very small area relative to the plot size. Although quantitative data is not reliable, visually each study site sampled during both 2011 and 2012 had fewer plants, which matches the trend seen in stem density estimates.

Percent cover data of lower forest strata, rocky ground cover, and coarse woody debris indicates *D. newtonianum* exists in a variety of types and amounts of ground cover. Plants were seen at the edge of rocky wet weather streams in or near the plot area at Gene Rush, Dave Manes Bluff, Calf Creek, and Woolum study sites.

As previously stated, the method used to estimate percent canopy cover was completed only at the center of each study site. There was a 33.4% difference from the lowest percent canopy cover to the highest, not including Dave Manes Bluff for which data were not available. However, this is a wide range for the amount of potential sunlight that reaches *D. newtonianum* plants on the forest floor. Plants at Point Peter north and Point Peter south, the sites with the lowest percent canopy cover during the 2012 field season, were in extremely poor condition. The exceptional drought during the summer of 2012 subjected plants to more sunlight, and hence more water evaporation, which was too much for the plants to handle. Plants were seen lying on ground, with little more than a stem and possibly the lowest leaf still attached. Other plants still capable of being erect were severely burnt, dry, and brown, especially near the apex. A majority of the buds and immature fruits seen in areas with direct sun were unable to fully develop due to the dry conditions. This also attributes to an inaccurate stem density count, as plants were probably missed that did not have buds, flowers, or leaves.

Soil pH ranges for *D. newtonianum* indicate the species can survive on both slightly acidic and slightly alkaline soils. The average percent humus for *D. newtonianum* sites varied more relative to *T. ozarkana* sites. Higher percent organic matter values from *D. newtonianum* sites can be attributed to those sites which were relatively flat and had wet weather streams

(Gene Rush, Dave Manes Bluff, and Woolum).

Neither factor analyses nor principal component analyses when regressed with site stem densities were found to be significant. Examination of the PC 1 and PC 2 score plot for *D. newtonianum* soil characteristics shows the study sites in three groups: one containing Calf Creek, Dave Manes Bluff, Gene Rush, and Woolum; another containing Buck Ridge, Point Peter south, and Point Peter unburned; and a third comprised only of Point Peter north. The cause for the separation of Point Peter north from the other groups is due to the site having the highest overall soil values for boron, iron, and sodium, as well as the lowest overall soil values for sodium, phosphorus, zinc, and potassium. It is interesting that Point Peter north was most unlike the others in soil composition, considering the close proximity to Point Peter south and Point Peter unburned (Figure 9.). Both Point Peter north and south were subjected to a wildfire in 1999, and Point Peter unburned was also subjected to a different wildfire in 2002, so differences in the soil composition are not due to fire (Budde 2004). The score plot of PC 1 and PC 2 of the physical parameters show all three Point Peter sites somewhat grouped together, meaning the overall physical parameters for those sites were similar to one another, which is expected. Woolum and Gene Rush study sites both loaded negatively on the score plot of PC 1, so parameter values that loaded positively high for PC 1, such as herbaceous cover, were low values for Woolum and Gene Rush; conversely, parameter values that loaded negatively high, such as bryophyte cover and rock cover, were high values for the two sites.

Euclidean distance values using plant species presence/absence data were smallest among the three Point Peter sites, which was expected given their location. Gene Rush and Woolum, the most mesic of the sites, were the most different from the other sites, including from each other (Table 16.). Woody tree species in common with most of the sites included *Carya* *cordiformis* (bitternut hickory), *Cercis canadensis* (redbud), *Fraxinus americana* (white ash), *Juglans nigra* (black walnut), *Quercus muehlenbergii* (chinquapin oak), and *Quercus rubra* (Northern red oak). Herbaceous plants common to most of the sites included *Amphicarpaea bracteata* (American hog-peanut), *Campanulastrum americanum* (American-bellflower), *Cynoglossum virginianum* (Southern wild comfrey), *Parthenocissus quinquefolia* (Virginia-creeper), *Polymnia canadensis* (white-flower leafcup), *Sanguinaria canadensis* (bloodroot), and *Toxicodendron radicans* (Eastern poison ivy). *Polymnia canadensis* and *Campanulastrum americanum* would be good candidate species to aid in searching for new undiscovered populations of *D. newtonianum* because they are seen less frequently than the other herbaceous species in common among the study sites.

Non-native and invasive plants found at *D. newtonianum* study sites covered more area than those at *T. ozarkana* sites. The Dave Manes Bluff site had four species of invasive plants including *Lespedeza cuneata* (sericea lespedeza), *Lonicera japonica* (Japanese honeysuckle), *Microstegium vimineum* (Japanese stiltgrass), and *Ailanthus altissima* (tree-of-heaven). An old road was present near the site, and the area was likely once a homestead. *Vinca* sp. (periwinkle) is also an invasive plant that was found at several of the *D. newtonianum* sites. These invasive plants can choke out native vegetation, and the number of threats for the Dave Manes Bluff site is alarming.

Habitat modeling for *D. newtonianum* using GIS was not successful with the initial model that used data from the 8 study site areas to output a raster using the Boolean operator "&". Zero of the 12 test points were correctly classified using this model. Examination of the suitable projected habitat shows that only small portions of Newton and Searcy counties were included (Figure 27.). As mentioned previously, the identifying characteristics in the attribute table of the soils layer includes slope percentages. Examination of the projected output for this model also shows abrupt changes from potential habitat in Searcy county near the border of Newton county, to no potential habitat on the opposite side of the political boundary. It is likely that there are multiple identification numbers for identical soil types in each county, and this would explain the abrupt change at the county lines.

The second model created for *D. newtonianum* using data from the study site areas and data extracted using the 12 test point locations used in the first model output a potential habitat area which correctly classified 19 of the 48 new test locations, or 40% (Figure 28.). The primary difference between this model and the initial model was the addition of 12 new soil identification numbers, one for each site.

The third model for *D. newtonianum* omitted the soil and geology layers and used only the ranked slope, elevation, and aspect rasters. The rankings created using the 20 data points omitted flat areas, elevations from 80 - 185 meters, 256 - 326, and 361 - 396, and slopes 0 - 10% from being included in the model (Figure 29.). The cell values for the majority of the test points did not have values from 5 - 9, the upper 50% of the possible values, but had raster values centered at a value of 5. The ranked habitat rasters when paired and added together did not correctly classify 8 of the 48 points in the elevation/slope raster, but did correctly classify all points in the aspect/slope raster and in the aspect/elevation raster. This indicates that aspect is the most important habitat variable for *D. newtonianum* out of the 3 variables used in the model.

The accuracy of the test point locations used in the models that were supplied by the Arkansas Natural Heritage Commission is unknown. Point data for some of the locations were listed as “last observed” in the late 1970’s. If locations were estimated using survey data from written directions, there is a high potential for significant deviations from the actual locations.

V. CONCLUSION

The distribution of data collected over the course of this project represent a step towards understanding the basis of each species. This has been accomplished indirectly by identifying characteristics of the the areas in which each is known to occur. Neither *Delphinium newtonianum* nor *Tradescantia ozarkana* appear to be habitat specialists, at least not in for the characteristics measured in this study; however, aspect for *D. newtonianum* and soil micronutrients for *T. ozarkana* appear to be important factors. Although the habitat modeling was only partly successful, with more research to identify the niche of each species, the use of GIS to delineate projected potential habitat is possible. As with many other species, loss of habitat and fragmentation of habitat are driving factors of species declination. No matter what the cause for the rarity of a particular species, preserving land on which it occurs cannot be stressed enough.

VI. LITERATURE CITED

Anderson, E., and K. Sax. 1934. A cytological analysis of self-sterility in *Tradescantia*. Botanical Gazette 95:609-621.

Anderson, E., and K. Sax. 1936. A cytological monograph of the American species of *Tradescantia*. Botanical Gazette 97:433-476.

Arkansas Natural Heritage Commission. 2013. http://www.naturalheritage.com/default.aspx (accessed on 10 March 2012).

Arkansas Natural Heritage Commission. 2011. Personal communication with Cindy Osborne.

Beilmann, A. P., and L. G. Brenner. 1951. A recent intrusion of forests in the Ozarks. Annals of the Missouri Botanical Garden 38:261-282.

Bourg, N. A., W. J. McShea, and D. E. Gill. 2005. Putting a cart before the search: successful habitat prediction for a rare forest herb. Ecology 86:2793–2804.

Braun, E. L. 1947. Development of the deciduous forests of eastern North America. Ecological Monographs 17:211-219.

Braun, E. L. 1950. Deciduous Forests of Eastern North America. The Blakiston Co. Philadelphia, Pennsylvania.

Budde, P. 2004. Buffalo National River Wildfire Polygons, 1983-2003. IRMA Portal. National Park Service. https://irma.nps.gov/App/Reference/Profile/1043456 (accessed on 31 March 2014).

Cox, G. W. 1985. Laboratory Manual of General Ecology, 5th ed. Wm. C. Brown Publishers, Dubuque, Iowa.

Damschen, E. I., S. Harrison, and J. B. Grace. 2010. Climate change effects on an endemic-rich edaphic flora: resurveying Robert H. Whittaker's Siskiyou sites (Oregon, USA). Ecology 91:3609-3619.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

Dettmers, R. and J. Bart. 1999. A GIS modeling method applied to predicting forest songbird habitat. Ecological Applications 9:152-163.

Dey, D. C., and G. Hartman. 2005. Returning fire to Ozark highland forest ecosystems: effects on advance regeneration. Forest Ecology and Management 217:37-53.

eFloras. 2008. Published on the internet http://www.efloras.org (accessed 27 March 2014). Missouri Botanical Garden, St. Louis, MO and Harvard University Herbaria, Cambridge, Massachusetts.

ESRI Inc. 2012. ArcGIS10.1. Redlands, California.

Faber-Langendoen, D., J. Nichols, L. Master, K. Snow, A. Tomaino, R. Bittman, G. Hammerson, B. Heidel, L. Ramsay, A. Teucher, and B. Young. 2012. NatureServe Conservation Status Assessments: Methodology for Assigning Ranks. NatureServe, Arlington, Virginia.

Farnsworth, E. J., and D. E. Ogurcak. 2006. Biogeography and decline of rare plants in New England: historical evidence and contemporary monitoring. Ecological Applications 16:1327-1337.

Foti, T.L. 1998. A description of the sections and subsections of the Interior Highlands of Arkansas and Oklahoma. Journal of the Arkansas Academy of Science 52:53-62.

Foti, T.L. 2008. The natural divisions of Arkansas. Arkansas Natural Heritage Commission, Little Rock, Arkansas.

Fowlkes, D. H., McCright, R. T., and Lowrance, J. S. 1987. Soil Survey of Newton County, Arkansas.

Geostor. 2014. http://www.geostor.arkansas.gov/G6/Home.html (accessed on 8 February 2014).

Gurevitch, J., S. M. Scheiner, and G. A. Fox. 2006. The Ecology of Plants, second edition. Sinauer Associates, Inc. Sunderland, Massachusetts.

Hardcastle, E. L., and J. L.Gentry. 2009. Conservation genetics of *Delphinium newtonianum* Dw. Moore (Moore's Delphinium) [Ranunculaceae], a rare endemic of the interior highlands. Southern Appalachian Botanical Society 74:41-52.

Hirzel, A. H., J. Hausser, D. Chessel, and N. Perrini. 2002. Ecological-niche factor analysis: how to compute habitat-suitability maps without absence data? Ecology 83:2027-2036.

Jackson, S. T., and C. Weng. 1999. Late quaternary extinction of a tree species in eastern North America. Pnas 96:13847-13852.

Jenkins, S. E., and M. A. Jenkins. 2006. Effects of prescribed fire on the vegetation of a savannah-glade complex in northern Arkansas. Southeastern Naturalist 5:113-126.

Kartesz, J. T., The Biota of North America Program (BONAP). 2013. *Taxonomic Data Center*. (http://www.bonap.net/tdc). Chapel Hill, N.C. [maps generated from Kartesz, J.T. 2013. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]

Koontz, J. A., P. S. Soltis, and D. E. Soltis. 2004. Using phylogeny reconstruction to test hypotheses of hybrid origin in *Delphinium* section Diedropetala (Ranunculaceae). Systematic Botany 29:345-357.

Kruckeberg, A. R., and D. Rabinowitz. 1985. Biological aspects of endemism in higher plants. Annual Review of Ecology and Systematics 16:447-479.

Laurent, G. D., Lowrance, J. S., and McCright, R. T. 1992. Soil survey of Searcy County, Arkansas.

Lefsky, M. A., W. B. Cohen, G. G. Parker, and D. J. Harding. 2002. Lidar remote sensing for ecosystem studies. BioScience 52:19-30.

Lesica, P., R. Yurkewycz, and E. E. Crone. 2006. Rare plants are common where you find them. American Journal of Botany 93:454-459.

Mann, L. K., A. W. King, V. H. Dale, W. W. Hargrove, R. Washington-Allen, L. R. Pounds, and T. L. Ashwood. 1999. The role of soil classification in geographic information system modeling of habitat pattern: threatened calcareous ecosystems. Ecosystems 2:524-538.

Matthies, D., I. Bra¨uer, W. Maibom, and T. Tscharntke. 2004. Population size and the risk of local extinction: empirical evidence from rare plants. Oikos 105:481-488.

McCune, B., M. J. Mefford. 1999. PC-ORD: Multivariate Analysis of Ecological Data; Version 4 for Windows. MjM Software Design.

Mildenhall, D. C., and M. L. Byrami. 2003. A redescription of *Podosporites parvus* (Couper) Mildenhall emend. Mildenhall & Byrami from the Early Pleistocene, and late extinction of plant taxa in northern New Zealand. New Zealand Journal of Botany 41:147-160.

Moore, D. M. 1939. *Delphinium*, a new species from the Arkansas Ozarks. Rhodora 41:193-197.

National Weather Service. 2012. Climate Statistics for Harrison, Arkansas. http://www.srh.noaa.gov (accessed 25 October 2013).

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer (accessed on 7 March 2013).

Oklahoma Natural Heritage Inventory. http://www.oknaturalheritage.ou.edu/ (accessed on 10 March 2012).

Pell, B. 1983. The natural divisions of Arkansas: a revised classification and description. Natural Areas Journal. 3:12-23.

Robison, H. W., and K. L. Smith. 1982. The endemic flora and fauna of Arkansas. Arkansas Academy of Science Proceedings 36:52-57.

SAS Institute Inc. 2013. JMP ® PRO 11.0.0. Cary, North Carolina.

Schoolcraft, H. R. 1821. Journal of a tour into the interior of Missouri and Arkansaw in the years 1818 and 1819. The New York Literary Journal and Belles Lettres Repository 2:256-265.

Skiles, A. (1981). Arkansas climate atlas. Arkansas Energy Office. Little Rock, Arkansas.

Smith, E. B. 1994. Keys to the Flora of Arkansas. The University of Arkansas Press, Fayetteville, Arkansas.

Stambaugh, M. C., and R. P. Guyette. 2006. Fire regime of an Ozark wilderness area, Arkansas. American Midland Naturalist 156:237-251.

Stebbins, G. L., and J. Major. 1965. Endemism and speciation in the California flora. Ecological Monographs 35:1-35.

Steyermark, J. A. 1963. Flora of Missouri. Iowa State University Press, Ames.

Store, R. and J. Jokimäki. 2003. A GIS-based multi-scale approach to habitat suitability modeling. Ecological Modelling 169:1-15.

Swallow, G. C. 1859. Geological report of the country along the line of the southwestern branch of the Pacific Railroad, State of Missouri. Printed by G. Knapp and Co., St. Louis, Missouri.

USDA, NRCS. 2012. The Plants Database. http://plants.usda.gov (accessed on 10 March 2012). National Plant Data Team, Greensboro, North Carolina.

USDA http://droughtmonitor.unl.edu/DataArchive/MapArchive.aspx (accessed on 25 October 2013)

US Fish and Wildlife Service. 2004. Endangered Species Act of 1973 as amended through the 108th Congress. Department of the Interior, Washington D.C.

US Fish and Wildlife Service. 2013. http://www.fws.gov/endangered/species/us-species.html (accessed on 18 May 2013).

Wilcove, D. S., and L. L. Master. 2005. How many endangered species are there in the United States? Frontiers in Ecology and the Environment 3:414-420.

Williams, J. N., C. Seo, J. Thorne, J. K. Nelson, S. Erwin, J. M. O'Brien and M. W. Schwartz. 2009. Using species distribution models to predict new occurrences for rare plants. Diversity and Distributions 15:565-576.

Williams, J. W., B. N. Shuman, and T. Webb III. 2001. Dissimilarity analysis of late-quaternary vegetation and climate in eastern North America. Ecology 82:3346-3362.

Witsell, T. Lead botanist at the Arkansas Natural Heritage Commission. Personal Communication thorough email. October 24, 2013.

Yatskievych, G. A., and Steyermark, J. A. 1999. Steyermark's flora of Missouri (Vol. 1). Missouri Department of Conservation, Jefferson City, Missouri.

Zomlefer, W. B. 1994. Guide to flowering plant families. The University of North Carolina Press. Chapel Hill, North Carolina.

VII. APPENDICES

Appendix A. Soil parameter values for *Tradescantia ozarkana* study sites. Note: Hwy = highway; lb/A = pounds per acre, ME/100g = milliequivalents of hydrogen per 100 grams of soil, and H_20 1:1 = 1 part soil to 1 part distilled water.

Parameter	**Centerpoint lower**	**Centerpoint upper**	**Hwy 43 lower**	**Hwy 43 upper**	**Kyles upper**	**Kyles lower**	**Red Fern lower**	**Red Fern upper**
Total exchange capacity (ME/100g)	21.98	14.46	15.23	11.94	17.03	13.56	14.43	13.22
pH (H_20 1:1)	6.5	7.1	6.7	6.1	6.5	6.6	6.7	6.4
Organic matter (%)	7.74	6.46	5.84	5.34	8.33	5.99	6.93	6.85
Estimated nitrogen release (lb/A)	114	107	104	102	117	105	110	109
Calcium (ppm)	2721	2377	2443	1591	2554	1932	1842	1797
Magnesium (ppm)	288	171	130	166	199	239	402	222
Potassium (ppm)	404	173	141	116	160	145	116	158
Sodium (ppm)	510	20	39	17	18	17	22	30
Sulfur (ppm)	14	10	10	10	10	7	10	9
Phosphorus (ppm)	33	26	15	33	41	14	17	16
Boron (ppm)	0.94	0.79	0.83	0.52	0.76	1.06	2.27	4.97
Iron (ppm)	48	56	60	85	54	123	91	65
Manganese (ppm)	401	333	375	147	311	186	303	245
Copper (ppm)	3.83	2.76	2.96	0.97	2.74	3.61	7.67	1.57
Zinc (ppm)	7.25	3.99	6.99	2.9	4.08	4.3	10.6	5.81
Aluminum (ppm)	826	602	484	496	677	457	546	504

Appendix B. Soil parameter values for *Delphinium newtonianum* study sites. Note: Hwy = highway; lb/A = pounds per acre, ME/100g = milliequivalents of hydrogen per 100 grams of soil, and H_20 1:1 = 1 part soil to 1 part distilled water.

Parameter	Buck Ridge	Calf Creek	Dave Manes Bluff	Gene Rush	Point Peter unburned	Point Peter north	Point Peter south	Woolum
Total exchange capacity (ME/100g)	16.56	22.52	22.79	24.76	11.67	17.27	17.19	22.68
pH (H_20 1:1)	6.6	6.4	6.6	7.5	6.2	6.8	7.5	7.1
Organic matter (%)	7.51	8.99	9.39	10.66	5.48	5.61	6.32	9.09
Estimated nitrogen release (lb/A)	113	120	122	125	102	103	107	120
Calcium (ppm)	2648	3600	3748	4353	1531	2800	2906	4090
Magnesium (ppm)	129	107	125	182	181	177	181	98
Potassium (ppm)	140	162	181	173	157	124	145	146
Sodium (ppm)	22	14	20	15	22	37	25	15
Sulfur (ppm)	10	8	10	8	9	7	9	11
Phosphorus (ppm)	38	32	45	40	29	10	40	15
Boron (ppm)	0.7	0.8	0.93	1.09	1.06	6.36	2.1	1.12
Iron (ppm)	78	80	98	79	76	135	59	84
Manganese (ppm)	164	158	148	217	303	172	280	194
Copper (ppm)	1.45	1.56	2.35	3.55	1.64	2.36	1.47	2.42
Zinc (ppm)	5.14	4.22	4.63	5.32	4.73	2.54	6.03	6.95
Aluminum (ppm)	491	379	441	356	775	491	497	286

Appendix C. Tree and shrub taxa associated with *Delphinium newtonianum*. Note: + indicates species presence; Wolm = Woolum; unbrn = unburned

Scientific name	Common name	Family name	Gene Rush	Wolm	Dave Manes Bluff	Point Peter north	Point Peter south	Point Peter unbrn	Buck Ridge	Calf Creek
Acer negundo	boxelder	Sapindaceae	+							
Ailanthus altissima	tree-of-heaven	Simaroubaceae			+					
Asimina triloba	pawpaw	Annonaceae		+			+	+	+	
Callicarpa americana	American beauty-berry	Lamiaceae					+	+		
Carya alba	mockernut hickory	Juglandaceae						+	+	
Carya cordiformis	bitternut hickory	Juglandaceae	+	+	+		+	+	+	+
Carya glabra	pignut hickory	Juglandaceae					+	+		
Carya ovata	shagbark hickory	Juglandaceae			+	+	+	+		
Carya texana	black hickory	Jugladaceae				+	+			
Celtis occidentalis	common hackberry	Cannabaceae			+	+	+	+	+	+
Cercis canadensis	redbud	Fabaceae	+	+	+	+	+	+	+	+
Cornus drummondii	rough-leaf dogwood	Cornaceae	+		+	+		+		+
Cornus florida	flowering dogwood	Cornaceae		+					+	
Diospyros virginiana	common persimmon	Ebenaceae				+				
Frangula caroliniana	Carolina false buckthorn	Rhamnaceae			+			+	+	+
Fraxinus americana	white ash	Oleaceae	+	+	+	+		+	+	+
Gleditsia triacanthos	honey-locust	Fabaceae			+				+	
Hamamelis cf. *virginiana*	American witch-hazel	Hamamelidaceae	+							
Ilex decidua	deciduous holly	Aquifoliaceae								+
Juglans nigra	black walnut	Juglandaceae		+	+	+		+	+	+
Juniperus virginiana	eastern red-cedar	Cupressaceae	+	+	+				+	+
Lindera benzoin	northern spicebush	Lauraceae	+	+	+					

Appendix C. (continued)

Scientific name	Common name	Family name	Gene Rush	Wolm	Dave Manes Bluff	Point Peter north	Point Peter south	Point Peter unbrn	Buck Ridge	Calf Creek
Liquidambar styraciflua	sweet-gum	Altingiaceae		+	+					
Maclura pomifera	osage-orange	Moraceae		+	+					
Morus rubra	red mulberry	Moraceae	+		+	+	+			
Ostrya virginiana	hophornbeam	Betulaceae	+	+					+	+
Platanus occidentalis	American sycamore	Platanaceae							+	
Prunus cf. *americana*	American plum	Rosaceae	+		+					
Prunus serotina	black cherry	Rosaceae			+	+	+	+		+
Quercus alba	white oak	Fagaceae			+	+	+	+	+	
Quercus muehlenbergii	chinquapin oak	Fagaceae	+	+	+	+	+		+	+
Quercus rubra	northern red oak	Fagaceae		+	+	+	+	+	+	+
Quercus stellata	post oak	Fagaceae			+	+				
Quercus velutina	black oak	Fagaceae	+							+
Rhus aromatica	fragrant sumac	Anacardiaceae			+		+	+		+
Rhus glabra	smooth sumac	Anacardiaceae				+	+	+		+
Ribes sp. A	goosebery	Grossularaceae						+		
Robinia pseudoacacia	black locust	Fabaceae				+	+	+		
Sambucus nigra ssp. *canadensis*	black elder	Adoxaceae		+						
Sassafras albidum	sassafras	Lauraceae			+		+	+	+	+
Sideroxylon lanuginosum	gum bully	Sapotaceae	+				+			+
Staphylea trifolia	American bladdernut	Staphyleaceae		+						
Symphorocarpus orbiculatus	coral-berry	Caprifoliaceae	+	+	+		+		+	+
Tilia americana	American basswood	Malvaceae			+					
Ulmus alata	winged elm	Ulmaceae		+	+	+	+		+	

Appendix C. (continued)

Scientific name	Common name	Family name	Gene Rush	Wolm	Dave Manes Bluff	Point Peter north	Point Peter south	Point Peter unbrn	Buck Ridge	Calf Creek
Ulmus americana	American elm	Ulmaceae		+						
Ulmus rubra	slippery elm	Ulmaceae	+			+	+		+	+
Vaccinium pallidum	early lowbush blueberry	Ericaceae							+	
Viburnum rufidulum	rusty blackhaw	Adoxaceae	+			+		+		+

Appendix D. Tree and shrub taxa associated with *Tradescantia ozarkana*. Note: + indicates species presence; Cp = Centerpoint; Hwy = Highway.

Scientific name	Common name	Family name	Cp lower	Cp upper	Red Fern lower	Red Fern upper	Hwy 43 lower	Hwy 43 upper	Kyles lower	Kyles upper
Acer rubrum	red maple	Sapindaceae			+					
Acer saccharum	sugar maple	Sapindaceae	+	+			+	+	+	+
Amelanchier arborea	downy service-berry	Rosaceae								+
Asimina triloba	pawpaw	Annonaceae	+		+	+		+	+	
Carpinus caroliniana	American hornbeam	Betulaceae			+					
Carya alba	mockernut hickory	Juglandaceae			+		+	+		+
Carya cordiformis	bitternut hickory	Juglandaceae	+		+	+	+		+	
Carya glabra	pignut hickory	Juglandaceae	+		+	+	+	+		
Carya ovata	shagbark hickory	Juglandaceae	+	+			+	+	+	+
Celtis occidentalis	common hackberry	Cannabaceae	+	+	+	+	+	+	+	
Cercis canadensis	redbud	Fabaceae			+	+	+	+	+	+
Cornus florida	flowering dogwood	Cornaceae			+	+				
Diospyros virginiana	common persimmon	Ebenaceae								+
Frangula caroliniana	Carolina buckthorn	Rhamnaceae							+	
Fraxinus americana	white ash	Oleaceae	+	+		+	+	+	+	+
Fraxinus quadrangulata	blue ash	Oleaceae	+		+		+	+	+	+
Gleditsia triacanthos	honey-locust	Fabaceae					+	+		
Juglans nigra	black walnut	Juglandaceae	+		+	+	+	+	+	
Juniperus virginiana	eastern red-cedar	Cupressaceae			+					
Lindera benzoin	northern spicebush	Lauraceae			+	+	+		+	+
Liquidambar styraciflua	sweet-gum	Altingiaceae			+					
Magnolia acuminata	cucumber-tree	Magnoliaceae			+					

Appendix D. (continued)

Scientific name	Common name	Family name	Cp lower	Cp upper	Red Fern lower	Red Fern upper	Hwy 43 lower	Hwy 43 upper	Kyles lower	Kyles upper
Morus rubra	red mulberry	Moraceae	+	+	+	+	+	+	+	+
Nyssa sylvatica	blackgum	Nyssaceae			+					
Ostrya virginiana	hophornbeam	Betulaceae			+				+	+
Platanus occidentalis	American sycamore	Platanaceae			+					
Prunus cf. *americana*	American plum	Rosaceae				+				
Prunus serotina	black cherry	Rosaceae	+		+	+			+	+
Quercus alba	white oak	Fagaceae			+	+	+	+		+
Quercus muehlenbergii	chinquapin oak	Fagaceae	+		+	+	+	+	+	
Quercus rubra	northern red oak	Fagaceae	+		+	+		+	+	+
Quercus stellata	post oak	Fagaceae		+						
Quercus velutina	black oak	Fagaceae			+		+			+
Rhus glabra	smooth sumac	Anacardiaceae		+						
Ribes sp. A	gooseberry	Grossulariaceae				+				
Robina pseudoacacia	black locust	Fabaceae		+		+	+	+		
Rosa carolina	Carolina rose	Rosaceae					+			
Rosa multiflora	multiflora rose	Rosaceae			+					
Sambucus nigra ssp. *canadensis*	black elder	Adoxaceae	+		+	+	+	+		
Sassafras albidum	sassafras	Lauraceae					+			+
Sideroxylon lanuginosum	gum bully	Sapotaceae				+				
Staphylea trifolia	American bladdernut	Staphyleaceae			+					
Symphoricarpos orbiculatus	coral-berry	Caprifoliaceae	+	+	+	+	+	+	+	
Tilia americana	American basswood	Malvaceae		+	+	+			+	+
Ulmus alata	winged elm	Ulmaceae			+			+	+	

Appendix D. (continued)

Scientific name	Common name	Family name	Cp lower	Cp upper	Red Fern lower	Red Fern upper	Hwy 43 lower	Hwy 43 upper	Kyles lower	Kyles upper
Ulmus americana	American elm	Ulmaceae	+						+	
Ulmus rubra	slippery elm	Ulmaceae		+	+	+	+	+		+
Viburnum rufidulum	rusty blackhaw	Adoxaceae			+	+				+

Appendix E. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Buck Ridge study site.

Scientific name	Common name	Family name
Ageratina altissima	white snakeroot	Asteraceae
Agrimonia rostellata	beaked grooveburr	Rosaceae
Antennaria sp. A	pussytoes	Asteraceae
Asarum canadense	Canadian wild ginger	Aristolochiaceae
Asplenium platyneuron	ebony spleenwort	Aspleniaceae
Boechera laevigata	smooth rockcress	Brassicaceae
Botrypus virginianus	rattlesnake fern	Ophioglossaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Cardamine sp. A	bittercress	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Clematis virginiana	devil's-darning-needles	Ranunculaceae
Commelina erecta	white-mouth dayflower	Commelinaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Cunila origanoides	dittany	Lamiaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Desmodium canescens	hoary tick-trefoil	Fabaceae
Elephantopus carolinianus	Carolina elephant's-foot	Asteraceae
Endodeca serpentaria	Virginia-snakeroot	Aristolochia
Fleischmannia incarnata	pink-slender thoroughwort	Asteraceae
Galium circaezans	licorice bedstraw	Rubiaceae
Geum canadense	white avens	Rosaceae
Hybanthus concolor	eastern green-violet	Violaceae
Lactuca sp. A	lettuce	Asteraceae
Lonicera japonica	Japanese honeysuckle	Caprifoliaceae
Osmorhiza longistylis	aniseroot	Apiaceae
Oxalis sp. A	wood sorrel	Oxalidaceae
Panax quinquefolius	American ginseng	Araliaceae
Parietaria pensylvanica	Pennsylvania pellitory	Urticaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Passiflora lutea	yellow passion-flower	Passifloraceae
Pedicularis canadensis	Canadian lousewort	Orobanchaceae
Phlox sp. A	phlox	Polemoniaceae
Phryma leptostachya	lopseed	Phrymaceae

Appendix E. (continued)

Scientific name	Common name	Family name
Podophyllum peltatum	May-apple	Berberidaceae
Polymnia canadensis	white leafcup	Asteraceae
Polystichum acrostichoides	Christmas fern	Dryopteridaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Sanicula sp. A	black-snakeroot	Apiaceae
Scutellaria sp. A	skullcap	Lamiaceae
Solidago caesia	wreath goldenrod	Asteraceae
Solidago ulmifolia	elm-leaf goldenrod	Asteraceae
Spigelia marilandica	woodland pinkroot	Loganiaceae
Thalictrum thalictroides	rue-anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sp. A	trillium	Trilliaceae
Verbesina alternifolia	wingstem	Asteraceae
Viola palmata	three-lobe violet	Violaceae
Viola pubescens	downy yellow violet	Violaceae
Woodsia obtusa	blunt-lobe cliff fern	Woodsiaceae

Appendix F. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Dave Manes Bluff study site.

Scientific name	**Common name**	**Family name**
Agrimonia rostellata	beaked grooveburr	Rosaceae
Ambrosia artemisiifolia	common ragweed	Asteraceae
Amphicarpaea bracteata	American hogpeanut	Fabaceae
Arisaema dracontium	greendragon	Araceae
Asarum canadense	Canadian wildginger	Aristolochiaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Campsis radicans	trumpet-creeper	Bignoniaceae
Carex sp. A	sedge	Cyperaceae
Carex sp. B	sedge	Cyperaceae
Chasmathium latifolium	Indian wood-oats	Poaceae
Clematis sp. A	leather-flower	Ranunculaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Desmodium paniculatum	panicled-leaf tick-trefoil	Fabaceae
Dichanthelium boscii	Bosc's rosette grass	Poaceae
Eupatorium serotinum	late-flowering thoroughwort	Asteraceae
Geum canadense	white avens	Rosaceae
Lespedeza cuneata	sericea lespedeza	Fabaceae
Lonicera japonica	Japanese honeysuckle	Caprifoliaceae
Menispermum canadense	common moonseed	Menispermaceae
Microstegium vimineum	Japanese stiltgrass	Poaceae
Parthenocissus quinquefolia	Virginia creeper	Vitaceae
Persicaria punctata	dotted smartweed	Polygonaceae
Persicaria virginiana	jumpseed	Polygonaceae
Polymnia canadensis	white-flower leafcup	Asteraceae
Polystichum acrostichoides	Christmas fern	Dryopteridaceae
Rubus sp. A	blackberry	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Scutellaria ovata	heart-leaf skullcap	Lamiaceae
Silene stellata	widow’s-frill	Caryophyllaceae
Smilax rotundifolia	horsebrier	Smilaceae
Spigelia marliandica	woodland pinkroot	Loganiaceae
Sporobolis sp. A	dropseed	Poaceae
Thaspium barbinode	hairy-joint meadow-parsnip	Apiaceae
Torilis arvensis	spreading hedge-parsley	Apiaceae

Appendix F. (continued)

Scientific name	Common name	Family name
Toxicodendron radicans	poison ivy	Anacardiaceae
Verbesina alternifolia	wingstem	Asteraceae
Verbesina virginica	white crownbeard	Asteraceae
Vinca major	greater periwinkle	Apocynaceae
unknown herbaceous dicot sp. A		

Appendix G. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Gene Rush study site.

Scientific name	Common name	Family name
Ageratina altissima	white snakeroot	Asteraceae
Agrimonia pubescens	soft grooveburr	Rosaceae
Agrimonia rostellata	beaked grooveburr	Rosaceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Asarum canadense	Canadian wild ginger	Aristolochiaceae
Blephilia ciliata	downy pagoda-plant	Lamiaceae
Boechera laevigata	smooth rockcress	Brassicaceae
Botrypus virginianus	rattlesnake fern	Ophioglossaceae
Brachyelytrum erectum	bearded shorthusk	Poaceae
Bromus pubescens	hairy woodland brome	Poaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Cryptotaenia canadensis	Canadian honewort	Apiaceae
Carex sp. A	sedge	Cyperaceae
Carex sp. B	sedge	Cyperaceae
Dichanthelium boscii	Bosc's rosette grass	Poaceae
Elephantopus carolinianus	Carolina elephant's-foot	Asteraceae
Euonymus obovatus	running strawberry-bush	Celastraceae
Galium aparine	sticky-willy	Rubiaceae
Galium circaezans	licorice bedstraw	Rubiaceae
Galium triflorium	fragrant bedstraw	Rubiaceae
Geranium maculatum	spotted crane's-bill	Geraniaceae
Geum sp. A	avens	Rosaceae
Hydrangea arborescens	wild hydrangea	Hydrangeaceae
Hylodesmum glutinosum	pointed-leaf tick-clover	Fabaceae
Ipomoea sp. A	morning-glory	Convolvulaceae
Lespedeza sp. A	bush-clover	Fabaceae
Osmorhiza longistylis	aniseroot	Apiaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Panicum sp. A	panic grass	Poaceae
Parthenocissus quinquefolia	Virginia creeper	Vitaceae
Persicaria virginiana	jumpseed	Polygonaceae
Phryma leptostachya	American lopseed	Phrymaceae
Polemonium reptans	Greek-valerian	Polemoniaceae
Polymnia canadensis	white leafcup	Asteraceae

Appendix G. (continued)

Scientific name	**Common name**	**Family name**
Polystichum acrostichoides	Christmas fern	Dryopteridaceae
Salvia lyrata	lyre-leaf sage	Lamiaceae
Sanicula sp. A	black-snakeroot	Apiaceae
Scutellaria sp. A	skullcap	Lamiaceae
Senecio sp. A	burnweed	Asteraceae
Silene stellata	widow's-frill	Caryophyllaceae
Smilax bona-nox	fringed greenbriar	Smilaceae
Smilax hispida	Chinaroot	Smilaceae
Smilax pulverlenta	downy carrion-flower	Smilaceae
Smilax rotundifolia	horsebriar	Smilaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Uvularia grandiflora	large-flower bellwort	Colchicaceae
Viola sororia	hooded blue violet	Violaceae
Viola sp. A	violet	Violaceae
Vitis sp. A	grape	Vitaceae
Zizia aurea	golden alexanders	Apiaceae
unknown woody dicot vine sp. A		

Appendix H. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Woolum study site.

Scientific name	Common name	Family name
Ageratina altissima	white snakeroot	Asteraceae
Agrimonia rostellata	woodland agrimony	Rosaceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Asarum canadense	Canadian wild ginger	Aristolochiaceae
Berchemia scandens	Alabama supplejack	Rhamnaceae
Blephilia ciliata	downy pagoda-plant	Lamiaceae
Carex sp. A	sedge	Cyperaceae
Clematis sp. A	leather-flower	Ranunculaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Desmodium pauciflorum	few-flower tick-clover	Fabaceae
Elephantopus carolinianus	Carolina elephant's-foot	Asteraceae
Galium circaezans	licorice bedstraw	Rubiaceae
Geum sp. A	avens	Rosaceae
Hackelia virginiana	beggar's-lice	Boraginaceae
Hydrastis canadensis	goldenseal	Ranunculaceae
Hylodesmum glutinosum	pointed-leaf tick-clover	Fabaceae
Menispermum canadense	Canadian moonseed	Menispermaceae
Microstegium vimineum	Japanese stiltgrass	Poaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Panicum sp. A	panic grass	Poaceae
Parthenocissus quinquefolia	Virginia creeper	Vitaceae
Phegopteris hexagonoptera	broad beech fern	Thelypteridaceae
Podophyllum peltatum	May-apple	Berberidaceae
Polymnia canadensis	white leafcup	Asteraceae
Polystichum acrostichoides	Christmas fern	Dryopteridaceae
Rubus sp. A	blackberry	Rosaceae
Rudbeckia laciniata var. *laciniata*	green-head coneflower	Asteraceae
Ruellia sp. A	wild petunia	Acanthaceae
Sanicula canadensis	Canadian black-snakeroot	Apiaceae
Smilax sp. A	greenbrier	Smilaceae
Spigelia marliandica	woodland pinkroot	Loganiaceae
Toxicodendron radicans	poison ivy	Anacardiaceae

Appendix H. (continued)

Scientific name	**Common name**	**Family name**
Verbesina virginica	white crownbeard	Asteraceae
Vinca sp. A	periwinkle	Apocynaceae
Viola pubescens	downy yellow violet	Violaceae
unknown woody dicot vine sp. A		

Appendix I. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Point Peter unburned study site.

Scientific name	**Common name**	**Family name**
Ambrosia trifida	giant ragweed	Asteraceae
Boechera laevigata	smooth rockcress	Brassicaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Carex sp. B	sedge	Cyperaceae
Clematis sp. A	leather-flower	Ranunculaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Desmodium obtusum	perplexed tick-trefoil	Fabaceae
Dichanthelium boscii	Bosc's rosette grass	Poaceae
Elymus hystrix	eastern bottle-brush grass	Poaceae
Erythronium rostratum	yellow trout-lily	Liliaceae
Euphorbia dentata	toothed euphorbia	Euphorbiaceae
Galium triflorum	fragrant bedstraw	Rubiacae
Geum sp. A	avens	Rosaceae
Osmorhiza longistylis	aniseroot	Apiaceae
Panicum sp. A	panic grass	Poaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Passiflora lutea	yellow passion-flower	Passifloraceae
Phryma leptostachya	lopseed	Phrymaceae
Podophyllum peltatum	May-apple	Berberidaceae
Polymnia canadensis	white-flower leafcup	Asteraceae
Rubus sp. A	blackberry	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Scutellaria sp.	skullcap	Lamiaceae
Smilax bona-nox	fringed greenbriar	Smilaceae
Smilax hispida	Chinaroot	Smilaceae
Solidago ulmifolia	elm-leaf goldenrod	Asteraceae
Thalictrum thalictroides	rue anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sessile	toadshade	Trilliaceae
Trillium virdiscens	taper-tip trillium	Trilliacae
Uvularia grandiflora	large-flower bellwort	Colchicaceae
Viola pubescens	downy yellow violet	Violaceae
Viola sp. A	violet	Violaceae

Appendix I. (continued)

Scientific name	**Common name**	**Family name**
Vitis sp. A	grape	Vitaceae
Woodsia obtusa	blunt-lobe cliff fern	Woodsiaceae

Appendix J. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Point Peter south study site.

Scientific name	**Common name**	**Family name**
Ageratina altissima	white snakeroot	Asteraceae
Ambrosia trifida	giant ragweed	Asteraceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Bromus tectorum	cheat grass	Poaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Campsis radicans	trumpet-creeper	Bignoniaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Clematis virginiana	devil's-darning-needles	Ranunculaceae
Clitoria mariana	Atlantic pigeonwings	Fabaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Dichanthelium boscii	Bosc's rosette grass	Poaceae
Dioscorea villosa	wild yam	Dioscoreaceae
Elymus hystrix	eastern bottle-brush grass	Poaceae
Erythronium rostratum	yellow trout-lily	Liliaceae
Euphorbia dentata	toothed spurge	Euphorbiaceae
Galium circaezans	licorice bedstraw	Rubiaceae
Galium triflorum	fragrant bedstraw	Rubiaceae
Geum canadense	white avens	Rosaceae
Helianthus cf. *hirsutus*	whiskered sunflower	Asteraceae
Ipomoea pandurata	man-of-the-Earth	Convolvulaceae
Maianthemum racemosum	feathery false Solomon's-seal	Ruscaceae
Matelea baldwyniana	Baldwin's milkvine	Apocynaceae
Menispermum canadense	Canadian moonseed	Menispermaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Phryma leptostachya	lopseed	Phrymaceae
Podophyllum peltatum	May-apple	Berberidaceae
Polymnia canadensis	white-flower leafcup	Asteraceae
Rubus sp. A	blackberry	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Scutellaria ovata	heart-leaf skullcap	Lamiaceae
Silene stellata	widow's-frill	Caryophyllaceae
Smilax bona-nox	fringed greenbriar	Smilaceae

Appendix J. (continued)

Scientific name	Common name	Family name
Smilax rotundifolia	horsebriar	Smilaceae
Solidago ulmifolia	elm-leaf goldenrod	Asteraceae
Symphyotrichum anomalum	many-ray American-aster	Asteraceae
Symphyotrichum oolentangiense	sky-blue-American-aster	Asteraceae
Thalictrum thalictroides	rue-anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sessile	toadshade	Trilliaceae
Trillium viridescens	taper-tip trillium	Trilliaceae
Uvularia grandiflora	large-flowered bellwort	Colchicaceae
Viola pubescens	downy yellow violet	Violaceae
Viola sp. A	violet	Violaceae
Vitis sp. A	grape	Vitaceae

Appendix K. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Point Peter north study site.

Scientific name	**Common name**	**Family name**
Ambrosia trifida	giant ragweed	Asteraceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Boechera sp. A	rockcress	Brassicaceae
Bromus tectorum	cheat grass	Poaceae
Camassia scilloides	Atlantic camas	Agavaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Campsis radicans	trumpet-creeper	Bignoniaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Cardamine sp. A	bittercress	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Clematis sp. A	leather-flower	Ranunculaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Desmodium obtusum	perplexed tick-trefoil	Fabaceae
Dichanthelium boscii	Bosc's rosette grass	Poaceae
Elymus hystrix	eastern bottle-brush grass	Poaceae
Erythronium rostratum	yellow trout-lily	Liliaceae
Helianthus cf. *hirsutus*	whiskered sunflower	Asteraceae
Lonicera japonica	Japanese honeysuckle	Caprifoliaceae
Muhlenbergia sp. A	fragile grass	Poaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Podophyllum peltatum	May-apple	Berberidaceae
Polymnia canadensis	white leafcup	Asteraceae
Rubus sp. A	blackberry	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Silene stellata	widow's-frill	Caryophyllaceae
Smilax cf. *rotundifolia*	horsebrier	Smilaceae
Solidago ulmifolia	elm-leaf goldenrod	Asteraceae
Spigelia marilandica	woodland pinkroot	Loganiaceae
Thalictrum thalictroides	rue-anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiacae
Vernonia baldwinii	western ironweed	Asteraceae
Viola sp. A	violet	Violaceae
Vitis sp. A	grape	Vitaceae

Appendix K. (continued)

Scientific name	Common name	Family name
Woodsia obtusa	blunt-lobe cliff fern	Woodsiaceae

Appendix L. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Calf Creek study site.

Scientific name	**Common name**	**Family name**
Ageratina altissima	white snakeroot	Rosaceae
Agrimonia rostellata	beaked grooveburr	Rosaceae
Allium sp. A	onion	Alliaceae
Ambrosia trifida	giant ragweed	Asteraceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Blephilia ciliata	downy pagoda-plant	Lamiaceae
Boechera laevigata	smooth rock cress	Brassicaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Campsis radicans	trumpet-creeper	Bignoniaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Chasmathium latifolium	Indian wood-oats	Poaceae
Clematis sp. A	leather-flower	Ranunculaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Desmodium sp. A	tick-trefoil	Fabaceae
Dichanthelium sp. A	rosette grass	Poaceae
Elymus virginicus	Virginia wild rye	Poaceae
Erythronium rostratum	yellow trout-lily	Liliaceae
Eupatorium serotinum	late-flowering thoroughwort	Asteraceae
Eupatorium sp. A	boneset	Asteraceae
Euphorbia commutata	tinted woodland spurge	Euphorbiaceae
Euphorbia cyanthphora	fire-on-the-mountain	Euphorbiaceae
Geranium maculatum	spotted crane's-bill	Geraniaceae
Geum canadense	white avens	Rosaceae
Heucera sp. A	alumroot	Saxifragaceae
Lonicera japonica	Japanese honeysuckle	Caprifoliaceae
Matelea sp. A	milkvine	Apocynaceae
Nabalus aspera	rough rattlesnake-root	Asteraceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Parietaria pensylvanica	Pennsylvania pellitory	Urticaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Passiflora lutea	yellow passion-flower	Passifloraceae

Appendix L. (continued)

Scientific name	Common name	Family name
Pedicularis canadensis	Canadian lousewort	Orobanchaceae
Phlox sp. A	phlox	Polemoniaceae
Podophyllum peltatum	May-apple	Berberidaceae
Polymnia canadensis	white leafcup	Asteraceae
Rubus sp. A	blackberry	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Sanicula sp. A	black-snakeroot	Apiaceae
Silene stellata	widow's-frill	Caryophyllaceae
Smilax bona-nox	fringed greenbriar	Smilaceae
Smilax rotundifolia	horsebrier	Smilaceae
Solidago sp. A	goldenrod	Asteraceae
Solidago ulmifolia	elm-leaf goldenrod	Asteraceae
Spigelia marliandica	woodland pinkroot	Loganiaceae
Stellaria media	common chickweed	Caryophyllaceae
Symphyotrichum oolentagiense	sky-blue American-aster	Asteraceae
Thalictrum thalictroides	rue-anemone	Ranunculacae
Thaspium barbinode	hairy-joint meadow-parsnip	Apiaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Valerianella sp. A	valerianella	Valerianaceae
Verbesina virginica	white crownbeard	Asteraceae
Vernonia arkansana	Arkansas ironweed	Asteraceae
Vinca major	greater periwinkle	Apocynaceae
Viola pubescens	downy yellow violet	Violaceae
Viola sp. A	violet	Violaceae
Vitis sp. A	grape	Vitaceae

Appendix M. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Redfern lower study site.

Scientific name	Common name	Family name
Agrimonia sp. A	agrimony	Rosaceae
Allium sp. A	wild onion	Alliaceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Arisaema dracontum	greendragon	Araceae
Arisaema triphyllum	Jack-in-the-pulpit	Araceae
Botrypus virginianus	rattlesnake fern	Ophioglossaceae
Camassia scilloides	Atlantic camas	Agavaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Cardamine hirsuta	hairy bittercress	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Carex sp. B	sedge	Cyperaceae
Chaerophyllum procumbens	spreading chervil	Apiaceae
Claytona virginica	Virginia spring beauty	Montiaceae
Clematis sp. A	leather-flower	Ranunculaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Delphinium carolinianum	Carolina larkspur	Ranunculaceae
Erythronium albidum	small white fawn-lily	Liliaceae
Erythronium rostratum	yellow-trout lily	Liliaceae
Galium sp. A	bedstraw	Rubiaceae
Geranium maculatum	spotted crane's-bill	Geraniaceae
Geum vernum	spring avens	Rosaceae
Hybanthus concolor	eastern green-violet	Violaceae
Impatiens capensis	spotted touch-me-not	Balsaminaceae
Iris cristata	dwarf crested iris	Iridaceae
Lactuca sp. A	lettuce	Asteraceae
Lamium purpureum	red henbit	Lamiaceae
Maianthemum racemosum	feathery false Solomon's-seal	Ruscaceae
Osmorhiza longistylis	aniseroot	Apiaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Panax quinquefolius	American ginseng	Araliaceae
Panicum sp. A	panic grass	Poaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Pedicularis canadensis	Canadian lousewort	Orobanchaceae

Appendix M. (continued)

Scientific name	**Common name**	**Family name**
Phlox sp. A	phlox	Polemoniaceae
Podophyllum peltatum	May-apple	Berberidaceae
Polygonatum biflorum	King Solomon's seal	Ruscaceae
Polymnia canadensis	white-flower leaf cup	Asteraceae
Polystichum acrostichoides	Christmas fern	Dryopteridaceae
Ranunculus sp. A	buttercup	Ranunculaceae
Ribes missouriense	Missouri gooseberry	Grossulariaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Sanicula odorata	clustered black-snakeroot	Apiaceae
Scutellaria ovata	heart-leaf skullcap	Lamaiceae
Silene virginica	fire-pink	Caryophyllaceae
Smilax bona-nox	fringed greenbriar	Smilaceae
Smilax rotundifolia	horsebriar	Smilaceae
Stellaria media	common chickweed	Caryophyllaceae
Thalictrum thalictroides	rue-anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sessile	toadshade	Trilliaceae
Uvularia grandiflora	large-flower bellwort	Colchicaceae
Viola pubescens	downy yellow violet	Violaceae
Viola sp. A	violet	Violaceae
unknown grass sp. A	grass	Poaceae
unknown grass sp. B	grass	Poaceae

Appendix N. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Redfern upper study site.

Scientific name	**Common name**	**Family name**
Ageratina altissima	white snakeroot	Asteraceae
Agrimonia rostellata	woodland agrimony	Rosaceae
Arisaema dracontium	greendragon	Araceae
Arisaema triphyllum	Jack-in-the-pulpit	Araceae
Asplenium sp. A	spleenwort	Aspleniaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Carex sp. A	sedge	Cyperaceae
Carex sp. B	sedge	Cyperaceae
Chaerophyllum procumbens	spreading chervil	Apiaceae
Clematis cf. *virginiana*	devil's-darning-needles	Ranunculaceae
Delphinium carolinianum	Carolina larkspur	Ranunculaceae
Desmodium sp. A	tick-trefoil	Fabaceae
Elymus hystrix	eastern bottle-brush grass	Poaceae
Galium circaezans	licorice bedstraw	Rubiaceae
Geum vernum	spring avens	Rosaceae
Hydrastis canadensis	goldenseal	Ranunculaceae
Impatiens cf. *capensis*	spotted touch-me-not	Balsaminaceae
Menispermum canadensis	moonseed	Menispermaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Parietaria pensylvanica	Pennsylvania pellitory	Urticaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Polymnia canadensis	white leaf-cup	Asteraceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Sanicula sp. A	black snake-root	Apiaceae
Scutellaria ovata	heart-leaf skullcap	Lamiaceae
Solidago caesia	wreath goldenrod	Asteraceae
Thalictrum thalictroides	rue-anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Viola pubescens	downy yellow violet	Violaceae
Vitis sp. A	grape	Vitaceae

Appendix O. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Highway 43 upper study site.

Scientific name	**Common name**	**Family name**
Arisaema triphyllum	Jack-in-the-pulpit	Araceae
Botrypus virginianus	rattlesnake fern	Ophioglossaceae
Brachyelytrum erectum	bearded shorthusk	Poaceae
Carex sp. A	sedge	Cyperaceae
Chaerophyllum procumbens	spreading chervil	Apiaceae
Chasmanthium latifolium	Indian wood-oats	Poaceae
Clematis catesbyana	satincurls	Ranunculaceae
Clematis virginiana	devil's-darning-needles	Ranunculaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Delphinium carolinianum	Carolina larkspur	Ranunculaceae
Desmodium sp. A	tick-trefoil	Fabaceae
Diarrhena cf. *americana*	American beakgrain	Poaceae
Dichanthelium boscii	Bosc's rosette grass	Poaceae
Dioscorea villosa	wild yam	Dioscoreaceae
Elymus hystrix	eastern bottle-brush grass	Poaceae
Endodeca serpentaria	Virginia-snakeroot	Aristolochiaceae
Galium aparine	sticky-willy	Rubiaceae
Galium concinnum	shining bedstraw	Rubiaceae
Galium sp. A	bedstraw	Rubiaceae
Geum vernum	spring avens	Rosaceae
Impatiens cf. *campensis*	spotted touch-me-not	Balsaminaceae
Maianthemum racemosum	feathery false solomon's-seal	Ruscaceae
Matelea sp. A	milkvine	Apocynaceae
Osmorhiza longistylis	aniseroot	Apiaceae
Parietaria pensylvanica	Pennsylvania pellitory	Urticaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Passiflora lutea	yellow passion-flower	Passifloraceae
Persicaria virginiana	jumpseed	Polygonaceae
Phlox pilosa	downy phlox	Polemoniaceae
Physalis sp. A	ground-cherry	Solonaceae
Pilea pumila	Canadian clearweed	Urticaceae
Polygonum sp. A	smartweed	Polygonaceae
Polymnia candensis	white-flower leaf cup	Asteraceae
Rubus sp. A	blackberry	Rosaceae

Appendix O. (continued)

Scientific name	Common name	Family name
Sanicula odorata	clustered black snakeroot	Apiaceae
Scutellaria elliptica	hairy skullcap	Lamiaceae
Silene stellata	widow's-frill	Caryophyllaceae
Smilax pulverulenta	downy carrion-flower	Smilaceae
Smilax rotundifolia	horsebriar	Smilaceae
Solidago sp. A	goldenrod	Asteraceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sessile	toadshade	Trilliaceae
Verbesina virginica	white crownbeard	Asteraceae
Viola pubescens	downy yellow violet	Violaceae

Appendix P. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Highway 43 lower study site.

Scientific name	Common name	Family name
Agrimonia rostellata	beaked grooveburr	Rosaceae
Anemone virginiana	thimbleweed	Ranunculaceae
Arisaema dracontium	greendragon	Araceae
Arisaema triphyllum	Jack-in-the-pulpit	Araceae
Asplenium trichomanes	maidenhair spleenwort	Aspleniaceae
Boechera laevigata	smooth rockcress	Brassicaceae
Botrypus virginianus	rattlesnake fern	Ophioglossaceae
Brachyelytrum erectum	bearded shorthusk	Poaceae
Carex sp. A	sedge	Cyperaceae
Chaerophyllum procumbens	spreading chervil	Apiaceae
Chasmanthium latifolium	Indian wood-oats	Poaceae
Claytonia virginica	spring beauty	Montiaceae
Clematis virginiana	devil's-darning-needles	Ranunculaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Cunila origanoides	dittany	Lamiaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Cystopteris protrusa	lowland bladder fern	Cystopteridaceae
Delphinium carolinianum	Carolina larkspur	Ranunculaceae
Diarrhena cf. *americana*	American beakgrain	Poaceae
Dichanthelium boscii	Bosc's rosette grass	Poaceae
Euphorbia commutata	tinted woodland spurge	Euphorbiaceae
Galium aparine	sticky-willy	Rubiaceae
Galium concinnum	shining bedstraw	Rubiaceae
Geum canadense	white avens	Rosaceae
Geum vernum	spring avens	Rosaceae
Heilanthus hirsutus	whiskered sunflower	Asteraceae
Hybanthus concolor	eastern green-violet	Violaceae
Maianthemum racemosum	feathery false solomon's-seal	Ruscaceae
Menispermum canadense	Canadian moonseed	Menispermaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Parietaria pensylvanica	Pennsylvania pellitory	Urticaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Persicaria virginiana	jumpseed	Polygonaceae
Phlox divaricata	wild blue phlox	Polemoniaceae

Appendix P. (continued)

Scientific name	Common name	Family name
Phyrma leptostachya	lopseed	Phrymaceae
Podophyllum peltatum	May-apple	Berberidaceae
Polymnia canadensis	white-flower leafcup	Asteraceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Sanicula sp. A	black-snakeroot	Apiaceae
Scutellaria elliptica	hairy skullcap	Lamiaceae
Smilax bona-nox	fringed greenbriar	Smilaceae
Smilax rotundifolia	horsebrier	Smilaceae
Symphyotrichum sp. A	American-aster	Asteraceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium recurvatum	bloody-butcher	Trilliaceae
Trillium sessile	toadshade	Trilliaceae
Viola pubescens	downy yellow violet	Violaceae
Viola sp. A	violet	Violaceae

Appendix Q. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Centerpoint lower study site.

Scientific name	**Common name**	**Family name**
Actaea racemosa	black bugbane	Ranunculaceae
Ageratina altissima	white snakeroot	Asteraceae
Agrimonia rostellata	woodland agrimony	Rosaceae
Ambrosia trifida	great ragweed	Asteraceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Antennaria parlinii	Parlin's pussytoes	Asteraceae
Arisaema dractonium	greendragon	Araceae
Botrypus virginianus	rattlesnake fern	Ophioglossaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Cardamine hirsuta	hairy bittercress	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Chaerophyllum procumbens	spreading chervil	Apiaceae
Chasmathium latifolium	Indian-woodoats	Poaceae
Clematis virginiana	devil's-darning-needles	Ranunculaceae
Commelina erecta	white-mouth dayflower	Commelinaceae
Corydalis flavula	yellow fumewort	Fumariaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Elephantopus carolinianus	Carolina elephant's-foot	Asteraceae
Elymus hystrix	eastern bottle-brush grass	Poaceae
Elymus sp. A	bottle-brush grass	Poaceae
Erythronium sp.	trout-lily	Liliaceae
Eupatorium serotinum	late-flowering thoroughwort	Asteraceae
Galium aparine	sticky willy	Rubiaceae
Galium circaezans	licorice bedstraw	Rubiaceae
Geranium maculatum	spotted crane's-bill	Geraniaceae
Geum sp. A	avens	Rosaceae
Hybanthus concolor	eastern green-violet	Violaceae
Hydrastis canadensis	goldenseal	Ranunculaceae
Impatiens capensis	spotted touch-me-not	Balsaminaceae
Laportea canadensis	Canadian wood-nettle	Urticaceae
Lithospermum latifolium	American gromwell	Boraginaceae
Maianthemum racemosum	feathery false Solomon's-seal	Ruscaceae
Menispermum canadense	Canadian moonseed	Menispermaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae

Appendix Q. (continued)

Scientific name	Common name	Family name
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Passiflora lutea	yellow passion-flower	Passifloraceae
Perilla frutescens	beefsteakplant	Lamiaceae
Persicaria sp.	smartweed	Polygonaceae
Persicaria virginiana	jumpseed	Polygonaceae
Phryma leptostachya	lopseed	Phrymaceae
Phytolacca americana	American pokeweed	Phytolaccaceae
Pilea pumila	Canadian clearweed	Urticaceae
Podophyllum peltatum	May-apple	Berberidaceae
Rubus sp. A	blackberry	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveracae
Sanicula odorata	clustered black-snakeroot	Apiaceae
Smilax pulverulenta	downy carrion-flower	Smilaceae
Solidago caesia	wreath goldenrod	Asteraceae
Solidago sp. A	goldenrod	Asteraceae
Stellaria media	common chickweed	Caryophyllaceae
Symphorotrichum oolentangiense	sky-blue American-aster	Asteraceae
Taraxacum officinale	common dandelion	Asteraceae
Thalictrum thalictroides	rue-anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sessile	toadshade	Trilliaceae
Verbesina virginica	white crownbeard	Asteraceae
Viola pubescens	downy yellow violet	Violaceae
Viola sp. A	violet	Violaceae
Vitis sp. A	grape	Vitaceae
unknown herbaceous dicot sp. A		

Appendix R. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Centerpoint upper study site.

Scientific name	Common name	Family name
Acalypha virginica	Virginia three-seed-mercury	Euphorbiaceae
Ambrosia artemisiifolia	annual ragweed	Asteraceae
Ambrosia trifida	great ragweed	Asteraceae
Antennaria parlinii	Parlin's pussytoes	Asteraceae
Asclepias quadrifolia	four-leaf milkweed	Apocynaceae
Boechera sp. A	rockcress	Brassicaceae
Cardamine hirsuta	hairy bittercress	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Chasmanthium latifolium	indian wood-oats	Poaceae
Clematis sp. A	leather-flower	Ranunculaceae
Commelina cf. *erecta*	white-mouth dayflower	Commelinaceae
Cunila origanoides	dittany	Lamiaceae
Dichanthelium cf. *boscii*	Bosc's rosette grass	Poaceae
Digitaria ischaemum	smooth crab grass	Poaceae
Elymus hystrix	eastern bottle-brush grass	Poaceae
Endodeca serpentaria	Virginia snakeroot	Aristolochiaceae
Euphorbia collorata	wood spurge	Euphorbiaceae
Galium aparine	sticky-willy	Rubiaceae
Galium circaezans	licorice bedstraw	Rubiaceae
Helianthus hirsutus	whiskered sunflower	Asteraceae
Heucera sp. A	alumroot	Saxifragaceae
Lactuca sp. A	lettuce	Asteraceae
Lespedeza frutescens	shrubby bush-clover	Fabaceae
Menispermum canadense	Canadian moonseed	Menispermaceae
Monarda sp. A	beebalm	Lamiaceae
Muhlenbergia schreberi	nimblewill	Poaceae
Orobanche uniflora	naked broom-rape	Orobanchaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Perilla frutescens	beefsteakplant	Lamiaceae
Phlox pilosa subsp. *ozarkana*	downy phlox	Polemoniaceae
Phytolacca americana	American pokeweed	Phytolaccaceae
Polygonum sp. A	smartweed	Polygonaceae
Potentilla simplex	old field cinquefoil	Rosaceae

Appendix R. (continued)

Scientific name	**Common name**	**Family name**
Prunella vulgaris	common self-heal	Lamiaceae
Scutellaria ovata	heart-leaf skullcap	Lamiaceae
Smilax rotundifolia	horsebriar	Smilaceae
Solidago sp. A	goldenrod	Asteraceae
Stellaria media	common chickweed	Caryophyllaceae
Symphyotrichum patens	late-purple American-aster	Asteraceae
Taraxacum officinale	common dandelion	Asteraceae
Thalictrum thalictroides	rue anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Triodanis perfoliata	clasping-leaf Venus'-looking-glass	Campanulaceae
Valerianella radiata	beaked cornsalad	Valerianaceae
Verbesina virginica	white crownbeard	Asteraceae
Viola sp. A	violet	Violaceae
Vitis sp. A	grape	Vitaceae
unknown herbaceous dicot sp. A		
unknown herbaceous dicot sp. B		
unknown herbaceous dicot sp. C		

Appendix S. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Kyles upper study site.

Scientific name	Common name	Family name
Arisaema triphyllum	Jack-in-the-pulpit	Araceae
Asplenium platyneuron	ebony spleenwort	Aspleniaceae
Boechera canadensis	sicklepod	Brassicaceae
Botrypus virginianus	rattlesnake fern	Ophioglossaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Carex sp. A	sedge	Cyperaceae
Eupatorium sp. A	boneset	Asteraceae
Euphorbia sp. A	spurge	Euphorbiaceae
Galium aparine	sticky-willy	Rubiaceae
Galium circaezans	licorice bedstraw	Rubiaceae
Galium sp. A	bedstraw	Rubiaceae
Hybanthus concolor	eastern green-violet	Violaceae
Lactuca sp. A	lettuce	Asteraceae
Maianthemum racemosum	feathery false Solomon's-seal	Ruscaceae
Menispermum canadense	common moonseed	Menispermaceae
Oxalis sp. A	wood-sorrel	Oxalidaceae
Parietaria pensylvanica	Pennsylvania pellitory	Urticaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Persicaria virginiana	jumpseed	Polygonaceae
Rosa carolina	Carolina rose	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveraceae
Sanicula odorata	clustered black-snakeroot	Apiaceae
Scutellaria ovata	heart-leaf skullcap	Lamiaceae
Silene stellata	widow's-frill	Caryophyllaceae
Solidago sp. A	goldenrod	Asteraceae
Symphyotrichum sp.	American-aster	Asteraceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sp. A	trillium	Trilliaceae
Triodanis perfoliata	clasping-leaf Venus'-looking-glass	Campanulaceae
Valerianella radiata	beaked cornsalad	Valerianaceae
Viola pubescens	downy yellow violet	Violaceae
Viola sp. A	violet	Violaceae
Vitis sp. A	grape	Vitaceae

Appendix T. List of herbaceous plants, seedless vascular plants, graminoids, and woody vines for the Kyles lower study site.

Scientific name	Common name	Family name
Actaea racemosa	black bugbane	Ranunculaceae
Agrimonia rostellata	beaked grooveburr	Rosaceae
Amphicarpaea bracteata	American hog-peanut	Fabaceae
Arisaema triphyllum	Jack-in-the-pulpit	Araceae
Asarum canadense	Canadian wild ginger	Aristolochiaceae
Campanulastrum americanum	American-bellflower	Campanulaceae
Cardamine concatenata	cut-leaf toothwort	Brassicaceae
Cardamine hirsuta	hairy bittercress	Brassicaceae
Carex sp. B	sedge	Cyperaceae
Carex sp. B	sedge	Cyperaceae
Clematis virginiana	devil's-darning-needles	Ranunculaceae
Cynoglossum virginianum	southern wild comfrey	Boraginaceae
Delphinium carolinianum	Carolina larkspur	Ranunculaceae
Dichanthelium sp. A	rosette grass	Poaceae
Erythronium sp. A	trout-lily	Liliaceae
Euphorbia sp. A	spurge	Euphorbiaceae
Galium aparine	sticky-willy	Rubiaceae
Galium circaezans	licorice bedstraw	Rubiaceae
Geum sp. A	avens	Rosaceae
Impatiens capensis	spotted touch-me-not	Balsaminaceae
Maianthemum racemosum	feathery false Solomon's-seal	Ruscaceae
Menispermum canadense	moonseed	Menispermaceae
Oxalis stricta	upright yellow wood-sorrel	Oxalidaceae
Panax quinquefolius	American ginseng	Araliaceae
Parietaria pensylvanica	Pennsylvania pellitory	Urticaceae
Parthenocissus quinquifolia	Virginia creeper	Vitaceae
Passiflora lutea	yellow passion-flower	Passifloraceae
Persicaria virginiana	jumpseed	Polygonaceae
Phlox pilosa subsp. *ozarkana*	downy phlox	Polemoniaceae
Podophyllym peltatum	May-apple	Berberdiaceae
Polystichum acrostichoides	Christmas fern	Dryopteridaceae
Prenanthes altissima	tall rattlesnake-root	Asteraceae
Rubus phoenicolasius	wine raspberry	Rosaceae
Sanguinaria canadensis	bloodroot	Papaveraceae

Appendix T. (continued)

Scientific name	Common name	Family name
Scutellaria ovata	heart-leaf skullcap	Lamiaceae
Silene stellata	widow's-frill	Caryophyllaceae
Smilax rotundifolia	horsebrier	Smilaceae
Symphyotrichum drummondii	Drummond's American-aster	Asteraceae
Symphyotrichum oolentangiensis	sky-blue American-aster	Asteraceae
Thalictrum thalictroides	rue-anemone	Ranunculaceae
Toxicodendron radicans	poison ivy	Anacardiaceae
Trillium sp. A	trillium	Trilliaceae
Uvularia grandiflora	large-flowered bellwort	Colchicaceae
Viola pubescens	downy yellow violet	Violaceae
unknown herbaceous dicot sp. A		

Appendix U. *Delphinium newtonianum* soil parameters eigenvector values for PC 1 – PC 7. Note: PC = principal component; Exchange = total exchange rate.

	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
Exchange	0.3305	0.2266	0.0473	0.0265	-0.0727	-0.0876	0.3026
pH	0.1261	0.0959	0.5258	-0.3465	-0.2818	0.1179	0.0310
Humus	0.3617	0.0817	0.0271	0.1220	0.0640	-0.0259	-0.2379
Nitrogen	0.3654	0.0734	-0.0309	0.1051	0.0022	0.0002	-0.1425
Calcium	0.3267	0.2276	0.0985	-0.0831	-0.0597	-0.0359	0.2329
Magnesium	-0.2129	-0.0084	0.5326	0.1848	0.0151	0.0966	-0.2086
Potassium	0.2485	-0.1419	0.0756	0.4798	0.2017	0.1383	0.5817
Sodium	-0.3120	0.2124	0.0578	-0.0567	-0.2174	0.4197	0.1289
Sulfur	0.1561	-0.2656	-0.2394	-0.3514	0.2137	0.6379	0.0616
Phosphorus	0.1522	-0.2704	0.1418	0.3872	-0.5395	0.3836	-0.0779
Boron	-0.2396	0.3765	0.1050	-0.1087	-0.0687	0.0628	0.3145
Iron	-0.1235	0.4435	-0.1632	0.0969	0.2411	0.3093	0.1102
Manganese	-0.1525	-0.3164	0.4036	-0.0894	0.2971	-0.2125	0.3512
Copper	0.1733	0.2780	0.3495	0.1003	0.5153	0.2106	-0.3624
Zinc	0.2054	-0.2936	0.1298	-0.4436	0.1186	0.0941	0.0341
Aluminum	-0.2893	-0.2541	0.0170	0.2633	0.2281	0.1406	-0.0342

Appendix V. Ps for linear regressions of stem densities against principal components and factors. Note: PC = principal component.

Species	Type of variables	Type of Analysis				
				Factor analysis		
Delphinium newtonianum		**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
	Physical	0.6972	0.0766	0.2182	0.6445	0.8822
	Soil	0.6217	0.4544	0.7304	0.1760	0.9420
				Principal Components Analysis		
		PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**
	Physical	0.2660	0.3377	0.4056	0.3395	0.5374
	Soil	0.7650	0.6512	0.5524	0.2414	0.1293
				Factor Analysis		
Tradescantia ozarkana		**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
	Physical	0.5099	0.1677	0.8088	0.1307	0.3909
	Soil	0.537	0.2353	0.0095	0.5736	0.8722
				Principal Components Analysis		
		PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**
	Physical	0.2124	0.8525	0.2575	0.5133	0.3331
	Soil	0.5202	0.0136	0.5313	0.4214	0.5215

Appendix W. *Delphinium newtonianum* soil parameters component loadings for PC 1 – PC 7. Note: PC = principal component; Exchange = total exchange rate.

	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
Exchange	0.8847	0.4363	0.0692	0.0342	-0.0595	-0.0621	0.1165
pH	0.3375	0.1847	0.7692	-0.4472	-0.2308	0.0836	0.0119
Humus	0.9682	0.1573	0.0396	0.1575	0.0525	-0.0183	-0.0915
Nitrogen	0.9780	0.1413	-0.0452	0.1357	0.0018	0.0001	-0.0548
Calcium	0.8744	0.4383	0.1441	-0.1072	-0.0489	-0.0255	0.0896
Magnesium	-0.5698	-0.0162	0.7791	0.2384	0.0124	0.0685	-0.0803
Potassium	0.6653	-0.2733	0.1106	0.6193	0.1652	0.0980	0.2238
Sodium	-0.8352	0.4090	0.0846	-0.0732	-0.1781	0.2975	0.0496
Sulfur	0.4178	-0.5114	-0.3502	-0.4535	0.1751	0.4522	0.0237
Phosphorus	0.4074	-0.5207	0.2074	0.4998	-0.4419	0.2719	-0.0300
Boron	-0.6412	0.7251	0.1536	-0.1403	-0.0563	0.0445	0.1210
Iron	-0.3305	0.8540	-0.2388	0.1251	0.1975	0.2192	0.0424
Manganese	-0.4081	-0.6094	0.5905	-0.1154	0.2434	-0.1506	0.1351
Copper	0.4640	0.5354	0.5113	0.1294	0.4221	0.1493	-0.1394
Zinc	0.5499	-0.5654	0.1898	-0.5726	0.0972	0.0667	0.0131
Aluminum	-0.7742	-0.4893	0.0248	0.3398	0.1868	0.0997	-0.0131

Appendix X. Correlation coefficients for soil parameters at *Delphinium newtonianum* study sites. Note: Exchange = total exchange capacity.

	Exchange	**pH**	**Humus**	**Nitrogen**	**Calcium**	**Magnesium**	**Potassium**	**Sodium**
Exchange	***	0.4271	0.9207	0.9220	0.9861	-0.4635	0.5083	-0.5592
pH	0.4271	***	0.3011	0.2597	0.5450	0.2992	-0.0452	-0.0420
Humus	0.9207	0.3011	***	0.9939	0.8941	-0.4790	0.6894	-0.7719
Nitrogen	0.9220	0.2597	0.9939	***	0.8911	-0.5580	0.6791	-0.7758
Calcium	0.9861	0.5450	0.8941	0.8911	***	-0.4282	0.4210	-0.5255
Magnesium	-0.4635	0.2992	-0.4790	-0.5580	-0.4282	***	-0.1500	0.5319
Potassium	0.5083	-0.0452	0.6894	0.6791	0.4210	-0.1500	***	-0.6925
Sodium	-0.5592	-0.0420	-0.7719	-0.7758	-0.5255	0.5319	-0.6925	***
Sulfur	0.0710	-0.0224	0.2375	0.2897	0.1214	-0.5795	0.1767	-0.4500
Phosphorus	0.1706	0.1017	0.3741	0.3842	0.1164	0.0726	0.6927	-0.4141
Boron	-0.0217	-0.5258	-0.0138	0.0423	-0.1256	-0.4394	-0.0391	-0.2078
Iron	0.0476	-0.2201	-0.1730	-0.1767	0.0260	0.0323	-0.3386	0.6280
Manganese	-0.5794	0.1883	-0.4825	-0.5346	-0.5224	0.6568	-0.0554	0.0686
Copper	0.6333	0.5042	0.6063	0.5324	0.6632	0.1828	0.3522	-0.1725
Zinc	0.2250	0.4665	0.3635	0.3711	0.3165	-0.2881	0.2123	-0.6293
Aluminum	-0.9040	-0.5195	-0.7629	-0.7803	-0.9372	0.5597	-0.1304	0.4195

Appendix X. (continued)

	Sulfur	**Phosphorus**	**Boron**	**Iron**	**Manganese**	**Copper**	**Zinc**	**Aluminum**
Exchange	0.0710	0.1706	-0.0217	0.0476	-0.5794	0.6333	0.2250	-0.9040
pH	-0.0224	0.1017	-0.5258	-0.2201	0.1883	0.5042	0.4665	-0.5195
Humus	0.2375	0.3741	-0.0138	-0.1730	-0.4825	0.6063	0.3635	-0.7629
Nitrogen	0.2897	0.3842	0.0423	-0.1767	-0.5346	0.5324	0.3711	-0.7803
Calcium	0.1214	0.1164	-0.1256	0.0260	-0.5224	0.6632	0.3165	-0.9372
Magnesium	-0.5795	0.0726	-0.4394	0.0323	0.6568	0.1828	-0.2881	0.5597
Potassium	0.1767	0.6927	-0.0391	-0.3386	-0.0554	0.3522	0.2123	-0.1304
Sodium	-0.4500	-0.4141	-0.2078	0.6280	0.0686	-0.1725	-0.6293	0.4195
Sulfur	***	0.1820	-0.2117	-0.4132	-0.0356	-0.1796	0.7595	-0.1586
Phosphorus	0.1820	***	0.0864	-0.5952	0.0633	-0.0608	0.2464	0.0593
Boron	-0.2117	0.0864	***	-0.1411	-0.3376	-0.6026	-0.2807	-0.0256
Iron	-0.4132	-0.5952	-0.1411	***	-0.5201	0.3082	-0.7471	-0.0672
Manganese	-0.0356	0.0633	-0.3376	-0.5201	***	-0.1672	0.3136	0.6183
Copper	-0.1796	-0.0608	-0.6026	0.3082	-0.1672	***	0.0245	-0.4690
Zinc	0.7595	0.2464	-0.2807	-0.7471	0.3136	0.0245	***	-0.3143
Aluminum	-0.1586	0.0593	-0.0256	-0.0672	0.6183	-0.4690	-0.3143	***

Appendix Y. *Delphinum newtonianum* physical parameter eigenvectors for PC 1 – PC 7. Note: PC = principal component; Canopy = % canopy cover; Slope = % slope; CWD = % coarse woody debris cover; Rock = % rock cover; Bryophytes = % bryophyte cover; Seedless = % seedless vascular plant cover; Woody = % woody plant cover; Graminoids = % graminoid cover; Herbaceous = % herbaceous cover; WRich = woody plant species richness; OtRich = plant species richness other than woody plants.

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
Canopy	-0.2800	0.2250	0.4787	-0.0772	-0.0326	-0.2117	**0.6112**
Slope	0.2487	0.2587	0.1125	0.4056	0.4453	0.4000	0.3976
Elevation	0.3216	-0.2515	0.0945	0.3171	0.4204	-0.2625	-0.1553
CWD	0.3261	-0.2721	0.2537	0.2796	-0.2562	-0.1869	0.0046
Rock	-0.3592	-0.0893	-0.2713	0.3265	0.0183	-0.2945	-0.0465
Bryophytes	**-0.4212**	-0.1452	-0.0681	0.2005	-0.1036	-0.0885	0.1106
Seedless	-0.2532	-0.4060	0.2043	-0.0640	0.0402	**0.7177**	-0.1594
Woody	0.2755	0.2515	0.1793	0.1932	**-0.6907**	0.1709	-0.0742
Graminoids	-0.0196	0.3370	**-0.6186**	0.1098	-0.0674	0.2027	0.1608
Herbaceous	0.3852	-0.1574	-0.3339	-0.0738	-0.0826	0.0018	0.2139
WRich	0.2012	0.1856	0.0425	**-0.6316**	0.1942	-0.1048	-0.0806
OtRich	-0.1195	**0.5615**	0.1918	0.2149	0.1397	-0.0215	-0.5663

Appendix Z. *Delphinum newtonianum* physical parameter loading scores for PC 1 – PC 7. Note: PC = principal component; Canopy = % canopy cover; Slope = % slope; CWD = % coarse woody debris cover; Rock = % rock cover; Bryophytes = % bryophyte cover; Seedless = % seedless vascular plant cover; Woody = % woody plant cover; Graminoids = % graminoid cover; Herbaceous = % herbaceous cover; WRich = woody plant species richness; OtRich = plant species richness other than woody plants.

	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
Canopy	-0.6169	0.3400	0.6441	-0.1015	-0.0279	-0.1399	**0.2417**
Slope	0.5478	0.3909	0.1513	0.5327	0.3820	0.2643	0.1572
Elevation	0.7085	-0.3801	0.1272	0.4165	0.3607	-0.1734	-0.0614
CWD	0.7184	-0.4111	0.3413	0.3672	-0.2199	-0.1234	0.0018
Rock	-0.7913	-0.1350	-0.3650	0.4289	0.0157	-0.1945	-0.0184
Bryo	**-0.9278**	-0.2195	-0.0916	0.2634	-0.0888	-0.0585	0.0437
Seedless	-0.5578	-0.6134	0.2748	-0.0840	0.0345	**0.4741**	-0.0630
Woody	0.6068	0.3800	0.2413	0.2538	**-0.5926**	0.1129	-0.0293
Gram	-0.0433	0.5092	**-0.8323**	0.1442	-0.0578	0.1339	0.0636
Herb	0.8485	-0.2379	-0.4493	-0.0969	-0.0708	0.0012	0.0846
WRich	0.4432	0.2804	0.0572	**-0.8295**	0.1666	-0.0692	-0.0319
OtRich	-0.2633	**0.8484**	0.2581	0.2822	0.1198	-0.0142	-0.2239

Appendix AA. Correlation coefficients for physical variables at *Delphinium newtonianum* study sites. Note: Canopy = % canopy cover; Slope = % slope; Elev = elevation; CWD = % coarse woody debris cover; Rock = % rock cover; Bryo = % bryophyte cover; Sd = % seedless vascular plant cover; Woody = % woody plant cover; Gram = % graminoid cover; Herb = % herbaceous cover; WRich = woody plant species richness; OtRich = plant species richness other than woody species

	Canopy	**Slope**	**Elev**	**CWD**	**Rock**	**Bryo**	**Sd**	**Woody**	**Gram**	**Herb**	**WRich**	**OtRich**
Canopy	***	-0.1712	-0.5272	-0.3765	0.1860	0.4332	0.2386	-0.1218	-0.3527	-0.8616	-0.0597	0.5330
Slope	-0.1712	***	0.5630	0.3637	-0.3613	-0.5101	-0.4199	0.4514	0.1495	0.2387	-0.0405	0.3836
Elevation	-0.5272	0.5630	***	0.8036	-0.3366	-0.5005	-0.2280	0.1904	-0.3180	0.5631	-0.0568	-0.2991
CWD	-0.3765	0.3637	0.8036	***	-0.4596	-0.4841	-0.1518	0.5715	-0.4753	0.5340	-0.1101	-0.3712
Rock	0.1860	-0.3613	-0.3366	-0.4596	***	0.9194	0.2974	-0.5414	0.3030	-0.5199	-0.7485	0.1294
Bryo	0.4332	-0.5101	-0.5005	-0.4841	0.9194	***	0.5713	-0.5569	0.0427	-0.7095	-0.7086	0.0892
Sd	0.2386	-0.4199	-0.2280	-0.1518	0.2974	0.5713	***	-0.4916	-0.4716	-0.4500	-0.3589	-0.3148
Woody	-0.1218	0.4514	0.1904	0.5715	-0.5414	-0.5569	-0.4916	***	0.0505	0.3311	0.0731	0.2305
Gram	-0.3527	0.1495	-0.3180	-0.4753	0.3030	0.0427	-0.4716	0.0505	***	0.2118	-0.0645	0.2461
Herb	-0.8616	0.2387	0.5631	0.5340	-0.5199	-0.7095	-0.4500	0.3311	0.2118	***	0.3495	-0.5960
WRich	-0.0597	-0.0405	-0.0568	-0.1101	-0.7485	-0.7086	-0.3589	0.0731	-0.0645	0.3495	***	-0.0700
OtRich	0.5330	0.3836	-0.2991	-0.3712	0.1294	0.0892	-0.3148	0.2305	0.2461	-0.5960	-0.0700	***

Appendix AB. Factor loadings for *D. newtonianum* physical variables. Note: Canopy = % canopy cover; Slope = % slope; CWD = % coarse woody debris cover; Rock = % rock cover; Bryophytes = % bryophyte cover; Seedless = % seedless vascular plant cover; Woody = % woody plant cover; Graminoids = % graminoid cover; Herbaceous = % herbaceous cover; WRich = woody plant species richness; OtRich = plant species richness other than woody plants.

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
OtRich	**0.8953**	-0.0210	0.2981	0.2835	0.1015
Canopy	0.8779	0.0260	-0.3465	-0.1849	0.0195
Bryophytes	0.1787	-0.7329	-0.0284	-0.2952	-0.2083
Seedless	-0.0202	-0.2915	-0.5943	-0.2273	-0.3013
WRich	0.0086	**1.0397**	0.0281	-0.1460	-0.1942
Herbaceous	-0.8135	0.2776	0.2322	0.1015	0.1715
Graminoids	-0.1536	-0.1565	**0.9944**	-0.0721	-0.0160
Rock	0.0402	-0.8065	0.2575	-0.0891	-0.2737
Slope	0.2464	0.0422	0.1408	**0.9125**	0.0554
Elevation	-0.3767	-0.0279	-0.2937	0.8203	-0.0618
Woody	0.0817	0.0225	0.0789	-0.0969	**1.0263**
CWD	-0.3712	-0.1285	-0.4652	0.3015	0.5763

Appendix AC. Factor loadings for *D. newtonianum* soil variables. Note: Exchange = total exchange rate.

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
Manganese	**0.9880**	0.2704	0.1138	0.0159	0.1833
Aluminum	0.8057	-0.1291	-0.0963	0.0764	-0.4551
Magnesium	0.7605	-0.5201	0.1774	0.1331	0.3076
Sodium	0.1477	-0.6040	-0.3898	-0.3035	0.1464
Sulfur	-0.0778	**0.9091**	-0.0983	-0.1321	-0.1006
Zinc	0.1252	0.9079	0.0294	0.0160	0.3823
Copper	0.0326	-0.1379	**0.9372**	-0.2600	0.1955
Potassium	0.0182	0.0602	0.6251	0.5749	-0.3158
Humus	-0.5086	0.1764	0.5318	0.2570	0.0649
Nitrogen	-0.5846	0.1978	0.4441	0.2763	0.0455
Exchange	-0.6726	0.0003	0.4232	0.1254	0.2470
Calcium	-0.6332	0.0750	0.4045	0.0417	0.3704
Iron	-0.2783	-0.5549	0.2059	-0.5909	-0.2456
Phosphorus	-0.0417	-0.1278	-0.1032	**1.0232**	0.0664
pH	-0.0197	0.0196	0.0816	0.0574	**0.9692**
Boron	-0.0105	-0.6321	-0.1294	-0.5126	0.2422

Appendix AD. *Tradescantia ozarkana* soil parameters eigenvector values for PC 1 – PC 7. Note: PC = principal component; Exchange = total exchange rate.

	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
Exchange	0.3504	0.0023	0.0088	-0.1268	0.0284	0.1848	-0.2686
pH	0.0644	0.1793	-0.6199	0.1461	0.0934	0.2284	0.5957
Humus	0.2827	0.0746	0.1665	0.4683	0.0938	0.1480	-0.1167
Nitrogen	0.2826	0.0762	0.1888	0.4524	0.1242	0.1244	-0.1337
Calcium	0.3016	-0.1098	-0.3373	0.0666	0.0575	0.1857	-0.3406
Magnesium	0.0923	0.4712	0.2981	-0.0431	0.1953	-0.0120	0.2758
Potassium	0.3090	-0.0520	0.1065	-0.3061	-0.1476	0.3757	0.1571
Sodium	0.2956	-0.0095	0.1627	-0.4167	-0.1362	0.2238	0.0408
Sulfur	0.3128	-0.0573	0.0795	-0.2631	-0.1277	-0.4224	0.2130
Phosphorus	0.1902	-0.3414	0.2310	0.1663	0.3550	-0.3200	0.2098
Boron	-0.0693	0.2382	0.2603	0.3204	-0.6552	0.1615	0.1743
Iron	-0.2544	0.1965	0.1560	-0.2239	0.3762	0.4137	-0.1449
Manganese	0.2931	0.1021	-0.3773	0.0254	-0.1726	-0.1521	-0.1815
Copper	0.0837	0.4993	-0.0694	-0.0548	0.3308	-0.1533	-0.0111
Zinc	0.1125	0.4899	-0.0299	-0.1082	-0.1481	-0.3527	-0.2701
Aluminum	0.3491	-0.0686	0.1097	0.0049	0.1009	0.0370	0.2762

Appendix AE. *Tradescantia ozarkana* soil parameters loadings. Note: PC = principal component; Exchange = total exchange rate.

	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
Exchange	0.9665	0.0041	0.0117	-0.1477	0.0306	0.1432	-0.1500
pH	0.1775	0.3198	-0.8278	0.1701	0.1005	0.1770	0.3326
Humus	0.7796	0.1330	0.2223	0.5454	0.1010	0.1147	-0.0652
Nitrogen	0.7795	0.1359	0.2521	0.5268	0.1337	0.0964	-0.0746
Calcium	0.8319	-0.1958	-0.4505	0.0776	0.0620	0.1439	-0.1902
Magnesium	0.2546	0.8403	0.3981	-0.0502	0.2103	-0.0093	0.1540
Potassium	0.8523	-0.0927	0.1422	-0.3565	-0.1589	0.2911	0.0877
Sodium	0.8154	-0.0170	0.2172	-0.4853	-0.1467	0.1735	0.0228
Sulfur	0.8627	-0.1021	0.1062	-0.3064	-0.1376	-0.3273	0.1189
Phosphorus	0.5246	-0.6089	0.3085	0.1937	0.3822	-0.2480	0.1171
Boron	-0.1911	0.4249	0.3476	0.3731	-0.7055	0.1251	0.0973
Iron	-0.7017	0.3505	0.2083	-0.2607	0.4051	0.3206	-0.0809
Manganese	0.8084	0.1821	-0.5038	0.0296	-0.1858	-0.1179	-0.1014
Copper	0.2308	0.8905	-0.0926	-0.0639	0.3562	-0.1188	-0.0062
Zinc	0.3102	0.8737	-0.0399	-0.1260	-0.1594	-0.2733	-0.1508
Aluminum	0.9629	-0.1223	0.1464	0.0057	0.1086	0.0287	0.1542

Appendix AF. Correlation coefficients for soil parameters at *Tradescantia ozarkana* study sites. Note: Exchange = total exchange capacity.

	Exchange	**pH**	**Humus**	**Nitrogen**	**Calcium**	**Magnesium**	**Potassium**	**Sodium**
Exchange	***	-0.7060	0.7054	0.7082	0.8375	0.2436	0.9014	0.8792
pH	-0.7060	***	-0.5577	-0.5376	-0.5683	-0.4604	-0.7448	-0.6747
Humus	0.7054	-0.5577	***	0.9986	0.5998	0.3815	0.5010	0.4207
Nitrogen	0.7082	-0.5376	0.9986	***	0.5855	0.4023	0.5002	0.4279
Calcium	0.8375	-0.5683	0.5998	0.5855	***	-0.1535	0.6508	0.5577
Magnesium	0.2436	-0.4604	0.3815	0.4023	-0.1535	***	0.1910	0.2753
Potassium	0.9014	-0.7448	0.5010	0.5002	0.6508	0.1910	***	0.9762
Sodium	0.8792	-0.6747	0.4207	0.4279	0.5577	0.2753	0.9762	***
Sulfur	0.7491	-0.4246	0.4441	0.4520	0.5614	0.1480	0.7218	0.7596
Phosphorus	0.4381	0.0952	0.5048	0.5245	0.3973	-0.1643	0.3557	0.3147
Boron	-0.1615	-0.3500	0.1966	0.1771	-0.3445	0.4832	-0.0914	-0.0940
Iron	-0.5653	0.3479	-0.5133	-0.4931	-0.6797	0.2816	-0.4861	-0.4120
Manganese	0.7644	-0.6860	0.5329	0.5148	0.8569	0.1032	0.5762	0.5368
Copper	0.2299	-0.4150	0.2657	0.2806	0.0606	0.8485	0.0320	0.1110
Zinc	0.3001	-0.4721	0.2428	0.2477	0.0747	0.7494	0.1552	0.2631
Aluminum	0.9153	-0.6387	0.7743	0.7797	0.7409	0.2468	0.8554	0.8088

Appendix AF. (continued)

	Sulfur	**Phosphorus**	**Boron**	**Iron**	**Manganese**	**Copper**	**Zinc**	**Aluminum**
Exchange	0.7491	0.4381	-0.1615	-0.5653	0.7644	0.2299	0.3001	0.9153
pH	-0.4246	0.0952	-0.3500	0.3479	-0.6860	-0.4150	-0.4721	-0.6387
Humus	0.4441	0.5048	0.1966	-0.5133	0.5329	0.2657	0.2428	0.7743
Nitrogen	0.4520	0.5245	0.1771	-0.4931	0.5148	0.2806	0.2477	0.7797
Calcium	0.5614	0.3973	-0.3445	-0.6797	0.8569	0.0606	0.0747	0.7409
Magnesium	0.1480	-0.1643	0.4832	0.2816	0.1032	0.8485	0.7494	0.2468
Potassium	0.7218	0.3557	-0.0914	-0.4861	0.5762	0.0320	0.1552	0.8554
Sodium	0.7596	0.3147	-0.0940	-0.4120	0.5368	0.1110	0.2631	0.8088
Sulfur	***	0.5479	-0.2016	-0.7610	0.6718	0.0919	0.3081	0.8139
Phosphorus	0.5479	***	-0.5598	-0.5019	0.1099	-0.2973	-0.4168	0.6783
Boron	-0.2016	-0.5598	***	0.0812	-0.0224	0.2625	0.5058	-0.1968
Iron	-0.7610	-0.5019	0.0812	***	-0.7209	0.2542	-0.0269	-0.6488
Manganese	0.6718	0.1099	-0.0224	-0.7209	***	0.3419	0.5034	0.6433
Copper	0.0919	-0.2973	0.2625	0.2542	0.3419	***	0.8381	0.1337
Zinc	0.3081	-0.4168	0.5058	-0.0269	0.5034	0.8381	***	0.1369
Aluminum	0.8139	0.6783	-0.1968	-0.6488	0.6433	0.1337	0.1369	***

Appendix AG. *Tradescantia ozarkana* physical variables eigenvector values for PC 1 – PC 7. Note: PC = principal component; Canopy = % canopy cover; Slope = % slope; CWD = % coarse woody debris cover; Rock = % rock cover; Bryophyte = % bryophyte cover; Seedless = % seedless vascular plant cover; Woody = % woody plant cover; Graminoids = % graminoid cover; Herbaceous = % herbaceous cover; WRich = woody plant species richness.

	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
Canopy	0.3257	-0.2836	-0.1779	0.3192	0.1743	**0.7212**	0.2129
Slope	**0.3892**	0.2494	0.2058	-0.2242	0.1778	0.1300	-0.3431
Elevation	0.3047	**0.4776**	-0.1056	0.0470	-0.1561	0.0527	-0.2298
CWD	-0.2250	0.3840	-0.2844	0.3381	0.3736	-0.2385	0.4454
Rock	0.3545	0.1865	0.1446	-0.4355	0.3136	0.0676	0.4088
Bryophyte	0.3242	-0.4042	0.1680	-0.1296	-0.1741	-0.3220	**0.4891**
Seedless	-0.3577	-0.0569	0.3004	-0.4316	0.0446	0.1013	0.0354
Woody	0.1287	0.1033	0.4976	**0.4499**	-0.5045	-0.0107	0.1135
Graminoids	0.0659	0.1092	**0.5791**	0.3297	**0.4919**	-0.1600	-0.0437
Herbaceous	-0.2682	0.4590	0.1450	-0.1446	-0.3135	0.4066	0.3924
WRich	-0.3839	-0.2171	0.3009	0.0816	0.2205	0.3062	-0.0967

Appendix AH. *Tradescantia ozarkana* physical parameter loadings for PC 1 – PC 7. Note: PC = principal component; Canopy = % canopy cover; Slope = % slope; CWD = % coarse woody debris cover; Rock = % rock cover; Bryophytes = % bryophyte cover; Seedless = % seedless vascular plant cover; Woody = % woody plant cover; Graminoids = % graminoid cover; Herbaceous = % herbaceous cover; WRich = woody plant species richness.

	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
Canopy	0.6825	-0.4394	-0.2520	0.3664	0.1276	**0.3492**	0.0717
Slope	0.8157	0.3863	0.2915	-0.2574	0.1301	0.0630	-0.1156
Elevation	0.6386	**0.7398**	-0.1496	0.0540	-0.1142	0.0255	-0.0774
CWD	-0.4716	0.5949	-0.4030	0.3882	0.2735	-0.1155	0.1501
Rock	0.7428	0.2890	0.2048	-0.5000	0.2296	0.0328	0.1377
Bryophytes	0.6794	-0.6261	0.2380	-0.1488	-0.1274	-0.1559	**0.1648**
Seedless	-0.7496	-0.0882	0.4256	-0.4955	0.0327	0.0491	0.0119
Woody	0.2697	0.1601	0.7050	0.5165	**-0.3693**	-0.0052	0.0382
Graminoids	0.1381	0.1691	**0.8204**	**0.3786**	0.3601	-0.0775	-0.0147
Herbaceous	-0.5620	0.7110	0.2055	-0.1660	-0.2295	0.1969	0.1322
WRich	**-0.8046**	-0.3363	0.4262	0.0936	0.1614	0.1483	-0.0326

Appendix AI. Correlation coefficients for physical variables at *Tradescantia ozarkana* study sites. Note: Canopy = % canopy cover; Slope = % slope; CWD = % coarse woody debris cover; Rock = % rock cover; Bryophyte = % bryophyte cover; Seedless = % seedless vascular plant cover; Woody = % woody plant cover; Gram = % graminoid cover; Herb = % herbaceous cover; WRich = woody plant species richness.

	Canopy	**Slope**	**Elevation**	**CWD**	**Rock**	**Bryophyte**	**Seedless**	**Woody**	**Gram**	**Herb**	**WRich**
Canopy	***	0.2494	0.1571	-0.3341	0.1958	0.5654	-0.7395	0.0791	-0.0303	-0.7596	-0.4044
Slope	0.2494	***	0.7448	-0.3613	0.9220	0.3745	-0.3879	0.3015	0.3633	-0.1139	-0.6519
Elevation	0.1571	0.7448	***	0.1744	0.5944	-0.0751	-0.6378	0.2522	0.0690	0.1484	-0.8334
CWD	-0.3341	-0.3613	0.1744	***	-0.3754	-0.8386	-0.0577	-0.2102	-0.0429	0.4751	0.0661
Rock	0.1958	0.9220	0.5944	-0.3754	***	0.4353	-0.2367	0.0530	0.2083	-0.1150	-0.6170
Bryophyte	0.5654	0.3745	-0.0751	-0.8386	0.4353	***	-0.2890	0.2281	0.0906	-0.7330	-0.2977
Seedless	-0.7395	-0.3879	-0.6378	-0.0577	-0.2367	-0.2890	***	-0.1840	0.0510	0.5320	0.7800
Woody	0.0791	0.3015	0.2522	-0.2102	0.0530	0.2281	-0.1840	***	0.7051	0.1101	0.0164
Gram	-0.0303	0.3633	0.0690	-0.0429	0.2083	0.0906	0.0510	0.7051	***	0.0486	0.2643
Herb	-0.7596	-0.1139	0.1484	0.4751	-0.1150	-0.7330	0.5320	0.1101	0.0486	***	0.2730
WRich	-0.4044	-0.6519	-0.8334	0.0661	-0.6170	-0.2977	0.7800	0.0164	0.2643	0.2730	***

Appendix AJ. Factor loadings for *Tradescantia ozarkana* soil variables. Note: Exchange = total exchange rate.

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
Sodium	**1.0533**	-0.1107	0.1008	-0.1302	-0.0281
Potassium	0.9589	0.0006	-0.0106	-0.0344	-0.0140
Sulfur	0.9062	0.0490	-0.0252	0.0102	-0.0275
Exchange	0.7359	0.2712	0.1027	0.1644	-0.1206
Aluminum	0.5975	0.5016	0.0292	0.0363	-0.1513
Nitrogen	0.0017	**0.9652**	0.1616	0.0504	0.1033
Humus	-0.0065	0.9600	0.1326	0.0855	0.1322
Phosphorus	0.1044	0.6876	-0.2754	-0.2861	-0.4273
Copper	-0.0282	0.0982	**0.9443**	0.2599	-0.1104
Magnesium	0.1248	0.2428	0.9252	-0.2069	0.1084
Zinc	0.3003	-0.1082	0.6963	0.2505	0.3382
Iron	-0.3693	-0.3253	0.5654	-0.3790	-0.2724
pH	-0.2516	-0.0344	0.1281	**0.9302**	-0.1153
Manganese	0.4607	0.1014	-0.0063	0.7193	0.0910
Calcium	0.3697	0.2887	-0.1998	0.5944	-0.2201
Boron	-0.1384	0.1151	-0.0167	-0.1661	**0.9664**

Appendix AK. *Tradescantia ozarkana* physical variables factor loadings. Note: Canopy = % canopy cover; Slope = % slope; Coarse woody debris = % coarse woody debris cover; Rock = % rock cover; Bryophytes = % bryophyte cover; Canopy = % canopy cover; Seedless vascular = % seedless vascular plant cover; Woody = % woody plant cover; Graminoid = % graminoid cover; Herbaceous = % herbaceous cover.

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
Rock	1.0097	0.0645	-0.1863	0.1305	-0.2196
Slope	0.9512	-0.0072	-0.1193	0.1631	0.0613
Elevation	0.7419	-0.0319	0.3223	-0.2360	0.3140
Bryophytes	0.1160	-0.3694	-0.7923	-0.0144	0.0853
Herbaceous	0.1050	0.8850	0.2575	-0.1135	0.2435
Seedless vascular	-0.1803	0.8083	-0.2807	0.1922	-0.2648
Coarse woody debris	-0.1063	-0.0320	1.0025	0.0961	-0.1142
Graminoid	0.1893	-0.0691	0.1504	0.9193	0.2810
Woody plant richness	-0.6431	0.2880	-0.0459	0.4862	-0.1057
Canopy	-0.0238	-0.9275	-0.0630	0.0392	0.0079
Woody plant	-0.0801	0.0453	-0.2226	0.2569	0.9369